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Assessing the Impact of Climate Change on Food Security of Communities in Turkana County.

BY

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DECLARATION

I, Anthony Njengi Burugu, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a project in any other university.

Signature:………………… Date:…………………

Anthony Njengi Burugu

F56/74733/2014

This project has been submitted for examination with my approval as the university supervisor

Signature:………………… Date:…………………

Dr.-Ing. Faith Njoki Karanja.

DEDICATION

I dedicate this project to my family, classmates and friends for the moral and material support they have given me throughout my life and for their great investment in my education

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ABSTRACT

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

The research study focused on using GIS and remote sensing tools and methods to analyses the impact of vegetation changes on food security as a result of climate change in Turkana County. This is because livestock has been identified as the main resource in this pastoral livelihood zone and the pasture /Vegetation condition reveals essential traits about the food security situation amongst pastoralist.

Satellite data, population data, livestock population data, covering period of 30 years where available was recorded and analyzed to reveal trends and impacts of their variances on food security. A sequence of NDVI datasets from the Advanced Very High Resolution Radiometer (AVHRR), and precipitation datasets for Turkana County was observed. Findings revealed that below normal rainfall occasioned by climate variability and change is persistent with effects on vegetation greenness and consequently pastures production in Turkana. Overall, the study area shows enhanced green vegetation coverage.

From the research is was noted that increasing temperatures and changing rainfall patterns have an impact on the quality of pasture and browse in Turkana County, with the border areas appearing more lush with stronger precipitation responses over time, probably due to the conflict Prone nature of border areas, making them unsuitable as grazing lands.

The results will help improve knowledge and understanding of the intricate impact of climate change on food security and hopefully lead to improved decision making in design of polices and measures aimed and protecting vital livelihoods and improving or adapting food security interventions' in Turkana.

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NOMENCLATURE

.mxd – ArcMap data format

.rst – Idrisi raster data format

ASAL _ Arid and Semi-Arid Land

AU – African Union

CHIRPS- Climate Hazards Group Infra-Red Precipitation with Station data

CIDP - County Integrated Development Plan

CSV – comma separated

DVDs - Digital Versatile Discs

FAO – Food and Agriculture Organization

FEG -Food Economy Group

GB - Gigabytes

GHz - Gigahertz

GIS /RS – Geographic Information System / Remote Sensing

GPS – Global Positioning System

HIV/AIDS - Human Immune-deficiency Virus / Acquired Immune-deficiency Syndrome

ILRI - International Livestock Research Institute

IPCC - Intergovernmental Panel on Climate Change

JPEG - Joint Photographic Experts Group (image compression technique)

KAP - Kerio Riverine Agro Pastoralist livelihood zone

KNBS - Kenya National Bureau of Statistics

KODI – Kenya Open Data Initiative

LGP - Length of the Growing Period

LTF - Lake Fishing livelihood zone

LUZ - Urban livelihood zone

MAM - March, April and May

NDVI – Normalized Difference Vegetation Index

OND - October, November and December

PC - Personal computer

PCA – Principal Content Analysis

RAM – Random Access Memory

TAP - Turkwel Riverine Agro-Pastoralist livelihood zone

TBP - Border Pastoralist Livelihood Zone.

TCP - Central Pastoralist livelihood zone

TIFF – Tagged Image File Format

WFP - World Food Program

WFS - World Food Summit

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

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

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

Climate change is a long-term problem with multiple uncertainties. Existing literature on climate change attributes increase in temperature to emission of greenhouse gases (carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons and others) produced by human activities (Hulme *et al.* 2001). Although the Earth's atmosphere contains numerous greenhouse gases, only carbon dioxide - CO2 accounts for overwhelming majority of the greenhouse effect that leads to climate change. Anthropogenic emissions of carbon dioxide account for about 63% of the greenhouse gas warming effects in the long-term and for 91% in the short-term (Yvon-Durocher *et al.* 2014). However, despite the irresistible evidence on the causes of climate change, there is still ongoing debate not only on its causes but also over the amount of change and what the change is likely to entails. For Kenya, the reported 0.7°C - 2.0°C increase in temperature during the last 40 years, together with variable and unpredictable rainfall, has limited pasture growth, increased water scarcity and exacerbate rangeland degradation in many arid-and semi-arid lands - ASALs (Mutimba *et al.* 2010; Hoang *et al.* 2014). The predicted changes in annual maximum and minim temperatures in East Africa by the late-twenty first century are 1.8°C and 4.3°C, respectively (IPCC 2012). In ASALs, heavy rains, droughts and floods are becoming more frequent, particularly in northern regions of Kenya (Kirkbride and Grahn 2008; Osano *et al.* 2013; Nicholson 2014).

Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns, (FAO:2008).

This study therefore aims at investigating the impact of climate change on food security in Turkana County, Climate variability and change in-terms of erratic rainfall and its uneven sequential and spatial distribution create frequent drought and flooding. Previous studies (Kabubo-Mariara 2008; Ericksen *et al.* 2013) have revealed that high spatial and temporal fluctuations in rainfall and temperatures have implications on the pastoral production system which is one of the dominant economic activities in the arid and semi-arid zones of Kenya and key driver and determinant of food security. That notwithstanding, pastoralism is seen to have immense potential for reducing poverty, generating economic growth, managing the environment, promoting sustainable development, and building climate resilience in arid and semi-arid ecosystems (African Union – AU 2010). This study will therefore focus on the key elements that lead to erosion of pastoral communities' food security in a regime of changing and variable climate.

1.2 Statement of the Problem

Northern Kenya represents a typical semi-arid region within East Africa and adverse effects of climate change are likely to impact negatively on the livelihood support base as well as ecosystem structure and function. Climate variability and change has exposed pastoralists, their herds and ecosystem to risk associated with frequent droughts and flooding (Birch and Grahn 2007).

The extreme climatic events often result in a number of adverse impacts including loss of livestock, a major source of livelihood and food security especially among pastoralist communities in the region. Majority of the pastoralists in northern Kenyan have not yet recovered from the impacts of the 1997 and 1999/2000 droughts, which are considered to be the longest and severest since 1950s (WFP, 2000). The 1998 El Nino rains produced an estimated five-fold increase in rainfall in the region compared to the long term average (Galvin *et al.* 2001)

During the recent 2008 - 2009 and 2010 - 2011 widespread droughts in the Horn of Africa, pastoralist lost approximately 60-70% of their livestock herd (Huho and Kosonei 2014), and about 3.2 million people were left in need of emergency assistance in arid and semi-arid regions of Kenya. For pastoralists, high livestock mortality has devastating effects on their lives and livelihoods. In fact, livestock is an integral form of pastoral capital, besides functioning as a means of production, storage, transport, transfer of food and wealth, and act as an insurance against weather risk such as drought (Behnke and Muthami 2011). Whilst pastoralists for a long has used indigenous ways of adapting to shock and stresses imposed by harsh environmental conditions, increasing frequency of extreme weather events is now bringing new challenges that constraints some of the adaptation strategies (Nassef *et al.* 2009; Ericksen *et al.* 2013)..(2011) famine has become increasingly common since 1990s and is undermining food security in the entire northern Kenya.

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

Therefore, this study demonstrates how GIS /RS technologies can lead to the development of better mitigation measures against the adverse impacts of climate change, lead to more informed resilience and adaptation programs development and hopefully be taken into consideration by county planners in the development of subsequent County Integrated Development Plans and hopefully lead to improved policies at all levels of planning.

1.3 Objectives

1.3.1. Overall Objective

The overall objective of this project is to apply GIS and remote sensing technologies in assessing the impact of Climate change on Food Security in Turkana County.

1.3.1 Specific Objectives.

The specific objectives are to:

i. identify relevant factors that affect food security in ASALS such as Turkana
ii. analyses the change in Vegetation cover in Turkana County.
iii. develop an information product that shows changes in key indicators of Livelihoods and food security.

1.4 Justification

A number of climate variability and change impact studies have been conducted on specific sectors such as water resources, agriculture, health, and rangelands ecosystems by using impact models and to a lesser extent socio-economic analyses (Smit and Wandel 2006; Eriksen and O'Brien 2007; Nassef et al. 2009). Global recommendation for Africa calls for an integrated assessment approach for vulnerability studies, at a more micro-scale to account for the influence of local contexts.(Intergovernmental Panel on Climate Change IPCC 2014). From the perspective of pastoral households, an understanding of vulnerability to climate variability and change is needed at the level that would specifically address specific geographic location so that the communities will get adequate lessons to tackle climate change impacts on Food Security with the precision that is necessary (Klein 2004). However, most of the scientific literature and discourses on vulnerability has concentrated on contributing to theoretical insights or analysis at a regional or national scale, with findings for each region, which have implication more for system wide planning (Fussel and Klein 2006; Hinkel 2011). For example, the sensitivity of agricultural systems (Galvin et al. 2004; Nhemachena and Hassan 2008; Roncoli et al. 2010; Bryan et al. 2013) or species (Thornton et al. 2006) to climate change have been examined in detail. While there is no superior scale of climate vulnerability analysis, recent studies by Yuga et al. (2010) and Marshall et al. (2014) have confirmed that micro-level analyses have been largely overlooked in favor of ecosystem-scale studies of biophysical vulnerability which affects food security negatively.

Hitherto, there is ambiguity and paucity of scientific information and in-depth analysis on household's vulnerability and change in adaptation strategies to climate variability in the ASALs of Kenya (Bryan et al. 2013). This study was therefore designed to provide more clarity on the scientific knowledge needed to strengthen households" adaptation strategies in response to the increasing climate variability and change in arid environments. Therefore, the current study contributes to the understanding of influence of climate variability and change on Food Security and coping strategies from an ASAL and a predominantly Pastoral livelihood zone perspective. This analysis is crucial for enhancing effective food security programs and strategies to confront future extreme climate events, and to update current science, public knowledge and policy discourses on climate change and food security.

1.5. Scope and Limitation of the Study

The study focused primarily on addressing the impact climate change has had on food security in Turkana County. This was done a through a careful consideration of key factors that determine food security in the ASALs.For Turkana, the assumption was made that the area being predominantly a pure pastoral livelihoods zone, vegetation as a source of food for livestock was a key factor that could be evaluated for the study. Population figures, current, past and projected were also analyzed to assess changes over time.

Due to constraints of time, data and resources the study was not able to assess food security at the household level or to investigate food production in the agro pastoral livelihood zones or to assess food markets, state of infrastructure, impacts, especially given changes experienced since the County system of governance commenced. The study was also not able also investigate the impact cross border and inter-communal conflicts amongst pastoral communities on Food security especially taking into consideration their seasonal variability based on weather conditions.

1.6. Organization of the report.

This study is presented in five chapters. Chapter One presents a general background to the study. The chapter also describes climate variability and change within the study context, and presents the research problem under investigation, objectives, justification, limitations of the study and the organization of the study. Chapter Two reviews literature on climate variability and change to highlight its impact on the people of Turkana County in Northern Kenya. Chapter Three provides a detailed description of the study area, and general methods used in this study. In Chapter Four, the trend of rainfall and population variability in arid environment of Turkana is analyzed. The link between vegetation dynamics and precipitation anomalies in the Turkana rangelands are also discussed in this chapter using satellite and actual precipitation datasets. Chapter Five summarizes the research findings and the main conclusions from all the chapters and implications for practice.

CHAPTER TWO
LITERATURE REVIEW

2.1 Background

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

There are predictions that due to accelerated anthropogenic and man-made activities, climate variability may increase in the future and that extremes might become more frequent in sub-Saharan Africa (Intergovernmental Panel on Climate Change IPCC 2014). The increased climate variability under projected scenarios is expected to augment food insecurity in the tropics, unless key investments are made to improve adaptive capacity of communities. Concern has been raised about viability of pastoralism which is practiced in sensitive environment characterized by high spatial and temporal variability in rainfall, and thus thought to be highly vulnerable to both present and future climate variability (Conway *et al.* 2005; Little 2012). However, contrasting past and present adaptation responses of pastoralist communities with those that are likely to be required in the future could give some indication of how trends in food security will change.

In this chapter published journal articles, government statistics, empirical evidences from case studies and other technical materials was synthesized to highlight climate variability and change, and draw lessons from previous and past adaptation strategies to climate stressors for Turkana pastoralist of north-western, Kenya. The changing climate conditions, especially the increased frequency and or severity of extreme events, will no doubt increase vulnerability to natural disasters such as droughts. At the same time, adverse climate impacts are considered disasters when they produce widespread damage and cause severe alterations in the normal functioning of community systems (Intergovernmental Panel on Climate Change IPCC 2012). However, the severity of impacts depends not only on the climate extremes but also on exposure, sensitivity and vulnerability of a community or a system (Gallopin 2006). In most instances, adaptation to climate variability and change focus mainly on reducing exposure and vulnerability `and increasing resilience to the potential adverse impacts of climate variability and extremes (Smit and Wandel 2006), even though risks cannot fully be eliminated. Despite numerous interpretations, the Intergovernmental Panel on Climate Change (IPCC 2012) report considers climate extremes as the occurrence of weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable.

The Turkana population has always been highly adaptive, a necessary trait given the weather variability that is characteristic of the arid and semi-arid ecosystems in which they inhabit in East Africa (Galvin 2009). Nonetheless, climate variability and change is forcing new levels of transformative adaptations among pastoral communities, and many are significantly affected by the consequences of their coping and adaptations strategies (Tsegaye *et al.* 2013). This raises the question to what extent past and present responses of pastoral communities and their system to climate variability and extremes facilitate their long-term adaptation to projected climate scenarios. Other studies have showed that adaptation to climate variability is necessary both to reduce current vulnerability to climatic extremes as well as to prepare for future climate variability and change (Adger *et al.* 2005; Notenbaert *et al.* 2013). While some adaptations may be developed specifically to cope with climate variability and projected change such as climate-proof infrastructures, adaptations often also involve policy, legal, institutional and financial responses to reduce sensitivity and increase adaptive capacity for resilience (Ford *et al.* 2013).

This chapter discussed how Turkana pastoralists have responded to frequent drought episodes and other climate stressors by keeping different types of livestock species, diversifying livelihood strategies, resources management and herd's mobility, sending children to school, migration to gain access to wage labour and self-employments. However, some of these strategies are challenged by emerging social, political, economic and environmental context which is likely to be different from the past context within which pastoralist communities have operated for centuries. For example, the depletions of the pasture resources and scarcity of water for livestock further complicate the ability of communities to live with climate variability and change (Ericksen *et al.* 2013). This is particularly problematic to vulnerable groups such as children, rural women and the elderly whose access to adaptation strategies is limited. In the past before 1970s, pastoralists in the Horn of Africa lived more sustainably through a series of institutionalized adaptive strategies where flexibility in time and space for accessing pasture and water resources was crucial, with strategies of herd diversification, discreet off-take rates that focused on selling male animals and less reproductive females, and exchange relationships with other nomads and sedentary households (Behnke and Scoones 1993; Little 2012). The second section of this chapter examines climate variability, extreme drought events and projected climate scenarios in Turkana, and the Horn of Africa in general. The third section discusses various livelihood strategies and elements that make the Turkana community able to withstand climate variability and extreme weather events, especially the recurrent drought episodes which has increased in frequency in the last two decades 1990s and 2000s. Then the fourth section reviews vulnerabilities and adaptation strategies to changing climate, while the fifth section examines policy environment for future adaptation to climate variability and extreme events in Turkana. The last section of this literature review highlights critical conclusions.

2.2 Climate Variability and Drought Impacts.

Drought events are the most important characteristic of climate variability and change in Turkana County. The region has experienced major incidences of droughts since 1960s, which have become more common from the late 1990s and 2000s. The following years 1960/1961, 1969, 1973/1974, 1979, 1980/1981, 1983/1984, 1991/1992, 1995/1996, 1999/2000, 2004/2006, 2008/2009, and 2010/11 had prolonged droughts with widespread direct and indirect effects on the lives and livelihoods (Osano *et al.* 2013; Huho and

Kosonei 2014). Further evidences from other climate models corroborates that there have been more Meteorological drought events in the Horn of Africa which are set to escalate in frequency and intensity in the future (Nicholson 2014). The challenges of recurrent droughts pose considerable challenges to the people of Turkana. Previous studies showed that drought is one of the main catalysts of food insecurity and malnutrition in the rangelands (Western 2010; Huho *et al.* 2011). The impacts of droughts on local population are manifested mainly through livestock mortality, water scarcity and land degradation.

The drought impact is amplified by increasing human population, privatization of communal lands and the associated sedenterisation, violent conflicts, weak governance, and reduced adaptive capacity of the households. These processes jointly heighten the vulnerability of pastoral communities, with increased poverty as a possible outcome (Eriksen and O'Brien 2007). The poverty which is an obstacle to effective adaptation in turn increases vulnerability of pastoralist to climate variability and change, a positive feedback mechanism which further deepens poverty. Turkana County will undoubtedly continue to experience a mixture of climate variability and extremes that are predicted for the greater Horn of Africa as a whole. Recent climate observation and modelling studies suggest median temperature increases which is likely to exceed 30C throughout Africa, including Kenya by the end of the 21st Century, roughly 1.5 times the Global mean response (Hulme *et al.* 2001; IPCC, 2007).

There is inconsistency in prediction of distribution in some of the future climate changes in Kenya due to incomplete understanding of the climate system and its inherent unpredictability. However, there is scientific consensus that dry seasons will warm more than wet seasons and the country's interior like the northern ASALs is likely to experience higher temperature increases than coastal regions (Thornton *et al.* 2006a). The global climate models predict shifts in rainy seasons, intense rains, and rainfall variability by up to 5-20% in Kenya by the year 2030 (World Wide Fund - WWF 2006). Changes in temperature and rainfall of this magnitude are likely to have a range of impacts on people, particularly those who derive a large portion of their livelihoods from weather dependent production systems such as pastoralism.

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

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

In addition, the general reduction in productivity which is projected for Kenya's ASALs such as Turkana will have important negative consequences for economic development potential of these area and will likely result in a shift in sectorial activities (Hulme *et al.* 2001; Easterling *et al.* 2007). Some projections suggest that decrease in the length of the growth period (LGP) and an increase in rainfall variability will render crop cultivation too risky and will result in a switch to more extensive livestock production systems (Thornton *et al.* 2006a). There is also likely to be a switch on species (for example from cattle to sheep, goats and camels) which are better adapted to more arid climatic conditions (Hulme *et al.* 2001; Easterling *et al.* 2007). Other changes include a greater frequency of loss of livestock assets as observed during the 2008/9 and 2010/11 drought events in the Horn of Africa. For example, during the 2008/9 widespread drought in Kenya, the livestock mortality was estimated at 40-70 per cent of the total herd (Zwaagstra *et al.* 2010). Like in most parts of the ASALs, loss of livestock was largely caused by starvation. Temperature and rainfall are important variables on livestock grazing and stocking strategies. However, other factors influencing decision making, are also key in shaping pastoralist production systems (Brooks 2006). Rather than singular stressors like drought shaping and dominating the environment, a range of other factors also need to be understood including the interaction of human settlements, climate change, and changes in land tenure impact on lives and livelihood. In Turkana and pastoral areas in general, much more work is required on how policy and understandings of climate changes are framed, reproduced and mainstreamed into practice. These various interactions can act as critical drivers of vulnerability as well with potential challenges including conflicts between different land use sectors.

2.3 Livelihood Strategies in Turkana.

The Turkana community largely depends on pastoralism system as their main livelihood production activity, which is made up of people, natural resources, livestock and social relations. Pastoralism is the principle livelihood and is assumed to have existed for more than 9,000 years in Turkana (Eaton 2010). Approximately 70% of the populations inhabiting the area are nomadic or semi-nomadic pastoralists. Turkana County is thought to have some of the highest number of livestock population in Kenya (Republic of Kenya 2010). The nomadic transhumance practiced by this ethnic community is characterized by risk-spreading and flexible mechanisms, such as mobility, communal land ownership, large and diverse herd sizes, and herd separation and splitting (Schilling *et al.* 2012). The livestock types kept to manage and spread risk include cattle, camels, goats, sheep and donkeys. Data obtained from Government statistics revealed a significant increasing trend for sheep and goats, while camel, donkey and cattle showed no trend pattern for the period 1993-2009 in Turkana (Table 4.2). Although there was no significant increase in camel population, the observed data indicate that their numbers have been on the increase, partly due to changing vegetation condition that favor browsers. The livestock species have different forage and water requirements with variable levels of resilience during drought periods. Livestock possession plays multiple social, economic and religious roles in pastoral livelihoods, such as providing a regular source of food in the form of milk, meat and blood for household members, cash income to pay for cereals, education, health care and other services. The Turkana livestock is also essential for payment of dowry, compensation of injured parties during raids, symbol of prosperity and prestige, currency for exchange, store of wealth and security against drought, disease and other calamities. Livestock is therefore an integral form of pastoral capital, besides functioning as a means of production, storage, transport and transfer of food and wealth (Behnke and Muthami 2011).

2.4 Contextualizing Food Security

The definition of food security adopted at the World Food Summit (WFS) in November 1996 states that "Food security exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

According to FAO "food security depends more on socio-economic conditions than on agro-climatic ones, and on access to food rather than the production or physical availability of food". It stated that, to evaluate the potential impacts of climate change on food security, "it is not enough to assess the impacts on domestic production in food-insecure countries.

One also needs to:

(i) assess climate change impacts on foreign exchange earnings; (ii) determine the ability of food surplus countries to increase their commercial exports or food aid; and (iii) analyze how the incomes of the poor will be affected by climate change" (FAO, 2003b:

365366). This study will however not extend to the latter two components as it goes beyond the scope of this study.

2.5 Assessing impact of climate change on Food Security using Geospatial Technologies:

Several strategies have been developed using Geospatial Information Systems (GIS) and Remote Sensing techniques, which contribute knowledge and understanding to food security. These strategies include techniques which examine local food environments, assess changes in land use and land cover, identify areas of importance in specific regions to determine the relationships between biophysical and socioeconomic attributes, and the use of 3D models to demonstrate landscape and construct methods to sustain our food sources. GIS and Remote Sensing play significant roles in securing the future of the world's food production and population. The importance of food security is directly linked to increases in population density, limitations on agriculture yields, and the spread of 'food deserts. (Kane 2014).

Many institutions employ use of GIS in food security monitoring, and analysis to determine appropriate interventions. A good example of the application of geospatial technologies to understand household food security is the Integrated Food Security Phase Classification (IPC) concept. Use of the IPC as a common classification framework for food security situation analysis continues to gain momentum among government, UN, NGO, donor, and academic organizations. The IPC has been introduced in several parts of Africa, Asia, Central America, and the Caribbean. Using Livelihood zone as the core unit of spatial analysis, the spatial extent of the various phases (Normal, Alert, Alarm and Emergency) analysts utilize a wide range of information sources and methods such as (existing geographic datasets, satellite imagery, GIS spatial analysis, key informants, focus groups, household/nutrition surveys, field observation, etc.) to arrive at the best approximation of the spatial extent of a given phase and to model hazards such as drought.

Currently GIS technology is also applied by donor agencies and UN implementing bodies to develop sustainable programs all over the world. The Food and Agriculture Organization FAO for example uses geospatial technology-satellite remote sensing, geographic information systems and global positioning systems - for comprehensive worldwide assessment and monitoring of environmental conditions related to sustainable agriculture development and food security. With the assessment and monitoring of land, water and natural resources, (FAO) produces a broad series of geospatial data and information, from land cover and land use change to poverty mapping uses Geographical Information Systems (GIS) databases in its appraisals of poverty, food security and rural studies, including vulnerability mapping.

2.6 Identified Gaps.

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

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

Insights from previous studies on climate variability impacts, vulnerability and adaptation processes are crucial in appreciating extent of the problem and need to design appropriate mitigation strategies at the regional, national and or local levels. However, much of the scientific knowledge for climate variability impacts on pastoralist fail to provide critical insights on the interaction between the climate variable and human factors at the micro or household level. Evidently past studies have identified a myriad of causes of food security in Kenya (Omosa, 1989). They range from natural to artificial, economic to political, and from internal to external.

No single factor can be cited as a cause to food insecurity, but the principal factor behind it is low household income poverty. As a result, the current study provides evidence for policy decisions with regards to the influence of climate variability and change on households vulnerability and their possibilities to cope with – and recover from climate shocks as a pre-requisite for enhancing resilience in the ASALs. Past studies have identified a myriad of causes of food security in Kenya (Omosa, 1989). They range from natural to artificial, economic to political, and from internal to external.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Study Area

3.1.1. Demographic aspects

Turkana County has a spatial extent of over 68,680.3 Km^2 which makes it one of the largest Kenya counties. It is expected to have an estimated human population of 1,427,797 persons by 2017 based on the 2009 population census projections. Turkana is considered one of the poorest counties with approximately 87.5% of its population having to live below the absolute poverty line (Kenya National Bureau of Statistics-KNBS, 2013). The main inhabitants of Turkana are the Turkana ethnic community whose major economic activity and source of livelihood is pastoralism (Watson and van Binsbergen, 2008). The people rear camels, cattle, sheep, goats and the donkey which have different forage and water requirements and consequently different levels of resilience to dry conditions as well. The people are also influenced by famine, malnutrition, epidemics, and sporadic community clashes with their immediate neighbours especially the Karamojong of Uganda and the Pokot from West Pokot. In most instances, the hazards experienced adversely impact on the people and are exhilarated by poorly developed infrastructure and low access to fundamental services, among other underlying causes of poverty experienced in northern Kenya region (Notenbaert *et al.,* 2013). The Turkana community are nomads and are known to move frequently with their animals as a result of the drought, conflicts and diseases outbreaks (Schilling *et al.,* 2012). Their search for pasture extends outwards towards the southern borders with West Pokot County, in habited by the Pokot pastoralists, and the western borders occupied by the Karamojong, the two groups with whom they share resources, use networks and raid from each other.

Previous research works show that rangeland degradation is now a common phenomenon which endangers the survival of the Turkana community that depend on this rangeland resource for their survival (Kigomo and Muturi, 2013). This degradation is attributed to factors such as over-exploitation of resources which is unavoidable as the population of both people and animals keep increasing, land use changes as privatization of land replaces communal land ownership, insufficient rainfall and poverty caused by changing climatic conditions. Managing frequent ASALs climatic fluctuations is therefore critical in sustaining the livelihoods of the communities affected.

3.1.2. Location and geo-physical aspects.

The study is focused on the vast northern Kenya, particularly on Turkana County. Turkana lies between longitude 34º 30' and 36º 40‘‘East and between latitude 10º 30' and 5º 30' North (Figure 3.1). It borders South Sudan and Ethiopia to the North and Uganda to the North-west, Baringo and West Pokot counties to the south and south western parts, Samburu to the South-East and Lake Turkana to the East. The climatic condition here is hot and dry throughout most of the year. The region is considered to have bimodal rains though with the long rains seasons experienced in March, April and May (MAM), while the short rains come in October, November and November (OND). The annual rainfall normally lies between 100mm and 500mm; a large part of which is contributed by the higher lands bordering Uganda all the way towards the Lake Turkana meanwhile the lowlands in the central parts of Turkana County receive least rainfall. Rainfall variability is thus extremely skewed temporally and spatially giving an intra-annual coefficient of variation of above 50% throughout the county, with peaks of 95% and more in the driest areas. The temperatures throughout the year are high ranging between 23°C, and 38°C, with a mean of 30°C. Sustaining livelihoods therefore requires adaptation to and management of the adverse weather conditions.

The vegetation is scarce consequently and ranges from scattered grassland and herbaceous plants to riverine woody trees species, although dwarf shrubs and bushes are predominant in most parts of the county (Coughenour and Ellis 1993). The woody trees are identified as Acacia mellifera, Acacia tortilis, Balanites aegyptiaca, Zizyphus mauritiana, Cordia sinensis and Dobera glabra. The vegetation is more along the border regions with Uganda. This necessitated introduction of fast growing plants to supplement the community’s demand for wood. The newly introduced species are as given, Acacia aneura, Atriplex aurionformis, Azandrachta indica, Parkinsonia aculeate and Acacia horosericea (Kariuki et al. 2008). The Turkana community though prefer Acacia reficiens, Abutilon frutico-sum and Cadaba rotundifolia for construction of animal pens, their houses and fencing while the majority of the other species are used for firewood.

The soil cover like in most of the ASALs is sand however other areas such as parts of the riverine zones have some black cotton soils (Van Bremen and Kinyanjui 1992). Most parts of rangelands are heavily overgrazed even the leafy and conflict prone borders with the Karamojong of Uganda. The grassland is also threatened by the invasive *Prosopis juliflora*.

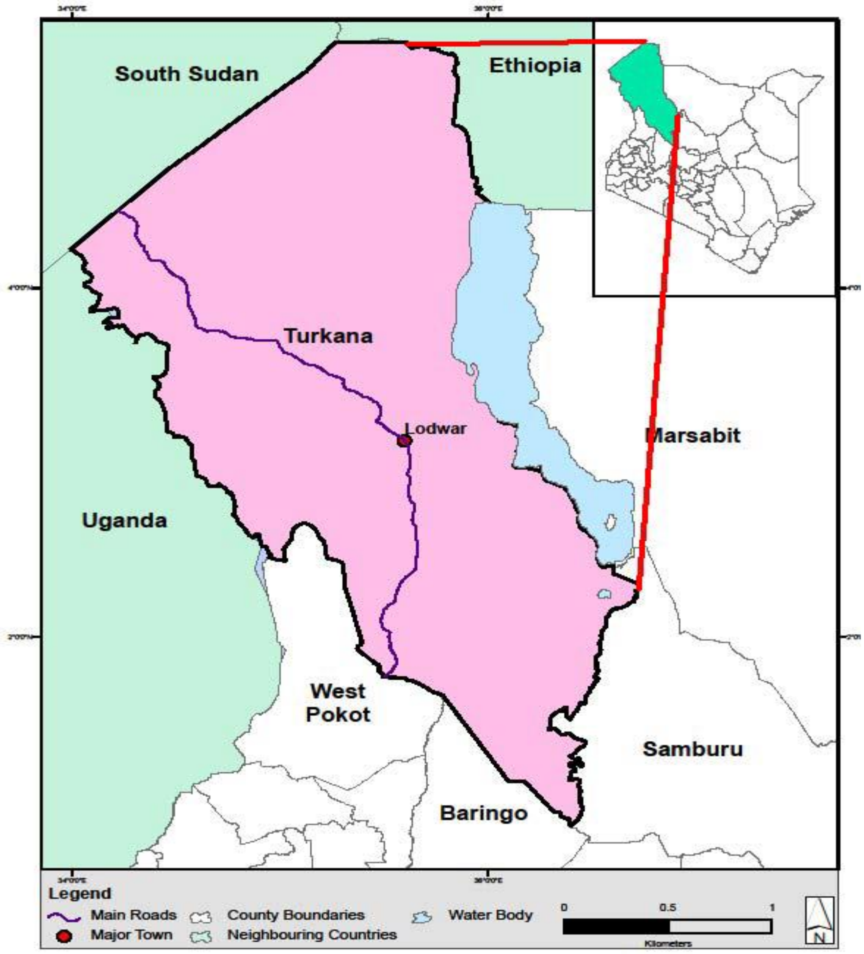


Figure 3.1: Map of Turkana County

3.2 Methodology

The methodology followed in this study involved the following steps as shown in greater detail in figure 3.2

i) Identification of the main factors that affect food security in the ASALS.
ii) Assembling of the relevant datasets.
iii) Developing a geo-referenced database of Turkana.
iv) Assessing and mapping the trend of the change of climate variables specifically rainfall.

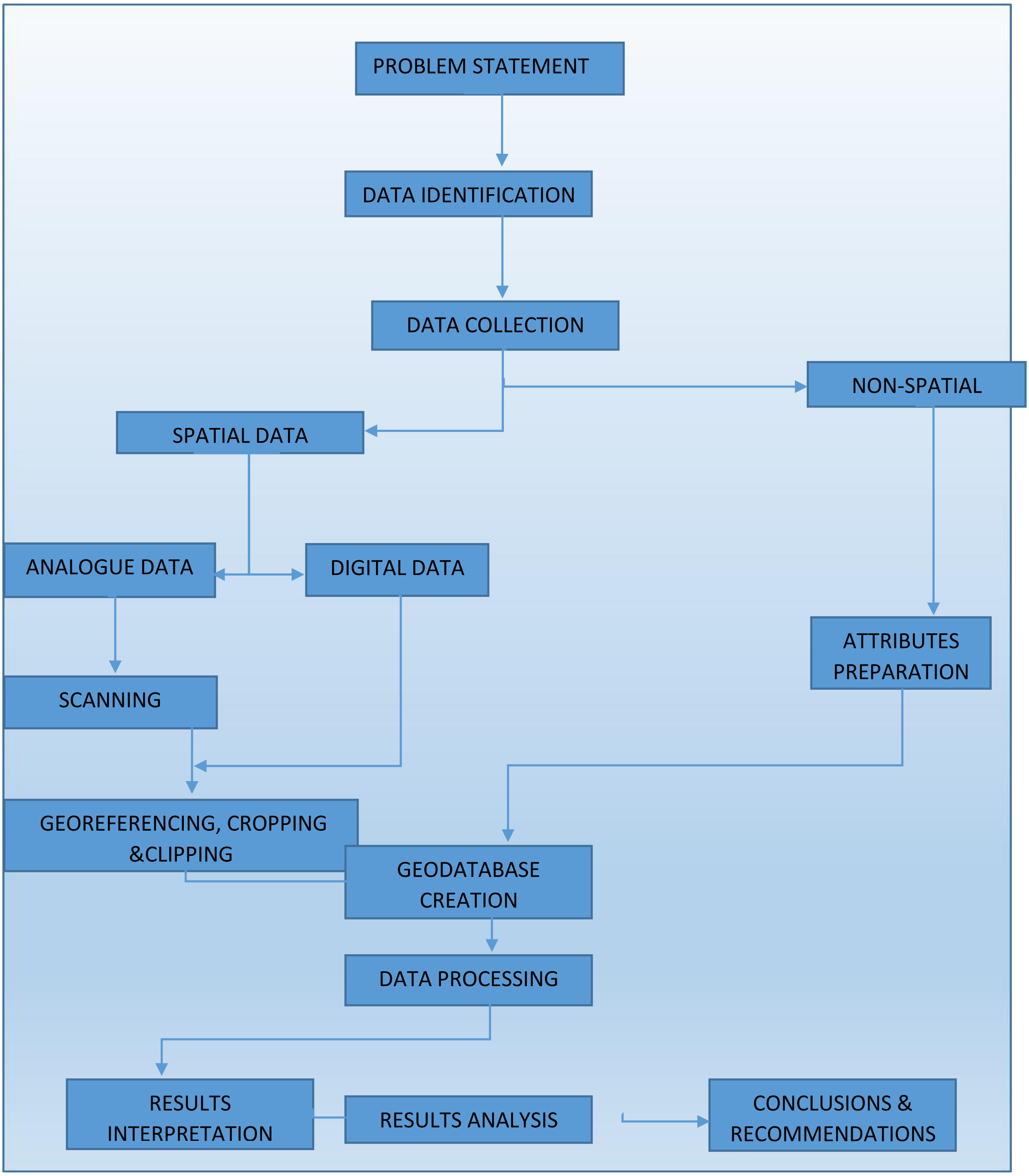


Figure 3.2: An overview of the study methodology

3.3 Data Sources and Tools

3.3.1. Data sources

The study utilized the following data whose sources will be as specified.

Rainfall data

This will be obtained from the CHIRPS (Climate Hazard Group Infrared Precipitation and Station) data which is a 5km resolution gridded data by USGS. It blends station based rainfall and satellite based rainfall estimates. This is the best continuous rainfall data available at present and is provided in pentadol averages (every 5days) from 1981 - to date. Rainfall totals for 5 days are represented in one pixel and the unit of measurement is the millimeter.

Population data:

This is available from the Kenya bureau of statistics.

Normalized Difference Vegetation Index (NDVI) satellite dataset

This was retrieved from International Livestock Research Institute (ILRI) database at Kabete, Nairobi.

Livestock and livelihood data in Turkana

This data is provided by the Food Economy Group (FEG)

Base map of Kenya Counties

This data was obtained from the Kenya Open Data Initiative (KODI).

3.3.2. Tools

The following tools were required for this project;

- A handheld GPS receiver

This was required for picking coordinates for ground referencing the collected spatial data and for spatial accuracy assessment.

- Computer hardware
    - ✓ Personal computer(PC) of the following minimum specifications; intel Atom, 1.86 GHz, 2 GB RAM and 500 GB Hard Disk
    - ✓ 4 DVDs

- ✓ HP printer
- ✓ 16 GB flash disk

The PC was the basic equipment in data processing and analysis. This included georeferencing, cropping and clipping the area of interest, determining the Normalized Difference Vegetation Index (NDVI) from the satellite imagery, analysis of the NDVIs for various years against each other and geographic visualization among others. Data storage was mainly in the computer hard disk. Back up storage was in the 16 GB flash drive. The DVDs were used for project submission in soft copy and for project back up storage. The printer was necessary in printing the final report for marking mainly.

- Computer Software
  - ✓ ArcGIS v 10.1
  - ✓ Global Mapper v 15
  - ✓ Microsoft office suite 2016
  - ✓ ERDAS Imagine / Idrisi Selva

These were used in data processing, analysis and visualization of spatial and non-spatial data.

3.4 Data Preparation

3.4.1 Data Evaluation

This aided further selection of useful data for the research project. Data completeness, the scale and data relevance were considered. Some of the data were excluded from the study based on dataset relevance while others that needed transformation were noted before preparing them for processing and analysis.

3.5 Data Processing

This involved procedures required in converting data to the relevant formats and harmonizing the various data for integration. This stage is necessary because of the following.

a) Varying data sources and scales.
b) Different storage formats of data used for instance; JPEG, TIFF, .mxd, .rst and csv formats among others.

c) Conversion from vector to raster would introduce varied errors associated with algorithms.

Data processing helped to bring all the datasets to a uniform scale, coordinate system, datum and projection. This also involved cropping the area of interest, georeferencing and mosaicking datasets.

The following are the selected datasets for the study and a brief description of their preparation and processing.

3.5.1 Generating NDVI Images.

CVB-MERIS-MVGT images of East Africa for the years 2001, 2007 and 2016 were cropped in Global Mapper version 15 and the area of interest exported in Idrisi file format. This is necessary to allow loading in Idrisi Selva. Idrisi Selva was used to compute the Normalized Difference Vegetation Index (NDVI). Different epochs from those considered for rainfall were used for NDVI to increase chances of predicting the emerging trend in climate variables especially precipitation.

NDVI formula for slope based calculation that was used is as follows:

$$NDVI = (N_{IR} - R) / (N_{IR} + R)$$

In which case, N_{IR} implies Near-Infrared &

R refers to Red

The calculation was done for 3 - distributed years from 2001 to 2016. There were 6 NDVI results per year allowing monthly analysis. The annual NDVI maps were also analyzed against each other consecutively to give the vegetation cover trend for Turkana County. This analysis relied on the use of the Principal Content Analysis (PCA) to establish the vegetation cover change over time.

3.5.2 Rainfall data processing

Climate Hazard Group Infrared Precipitation and Station (CHIRPS) provides 5km resolution continuous rainfall data per region. This data is gridded by USGS which blends station based rainfall and satellite based rainfall estimates. It is available in pentadol averages (every 5days) since 1981 which implies that every pixel represents rainfall totals for 5 days. The units of measurement used are the mm.

This study considered the period between 1986 and 2015 taking into account the MAM and OND seasons. This is because previous research works indicate that Turkana mainly receives rainfall during the two seasons. The seasons are the long rains (March, April and May) season and the short rains (October, November and December) season. A sufficient epoch of 10 years was used to classify the MAM data then OND data as well.
This data was cropped to Turkana County which is the area of interest to facilitate faster rainfall trend analysis. The statistical summary for seasonal, annual and mean rainfall were also established.

3.5.3 Population data processing

Statistical data was obtained from Turkana County Integrated Development Plan (CIDP 2013-2017). This data provides information for 2009 Census and the population projection for the years 2012, 2015 and 2017. Data processing involved data organization into tables and generation of graphs.

3.6 Assessing the impact of climate change on Food Security:

The datasets were then combined to present an overlay of the rainfall patterns vis a vis a trend pattern showing population trends against availability of vegetation for livestock. This was done for the various epochs to present the change over time and to make the study viable as a climate change impact assessment.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Introduction

This section contextualises the results of the study and offers a discussion of the results obtained.

4.2 NDVI

There were six NDVI maps for every year. Obtaining epochal averages was therefore necessary for quick analysis. This was done in ArcMap 10.2.1 using the Raster Calculator tool which uses a matrix to compute raster data cell by cell. Therefore, considering a number of raster layers with say a pixel at row x1 and column y1, all the digital values recorded at this particular pixel location are calculated locally throughout the images included in the sample. Average values for NDVI datasets were determined by dividing the totals for the annual raster by the number of the sample that year. This is captured in the diagram below.

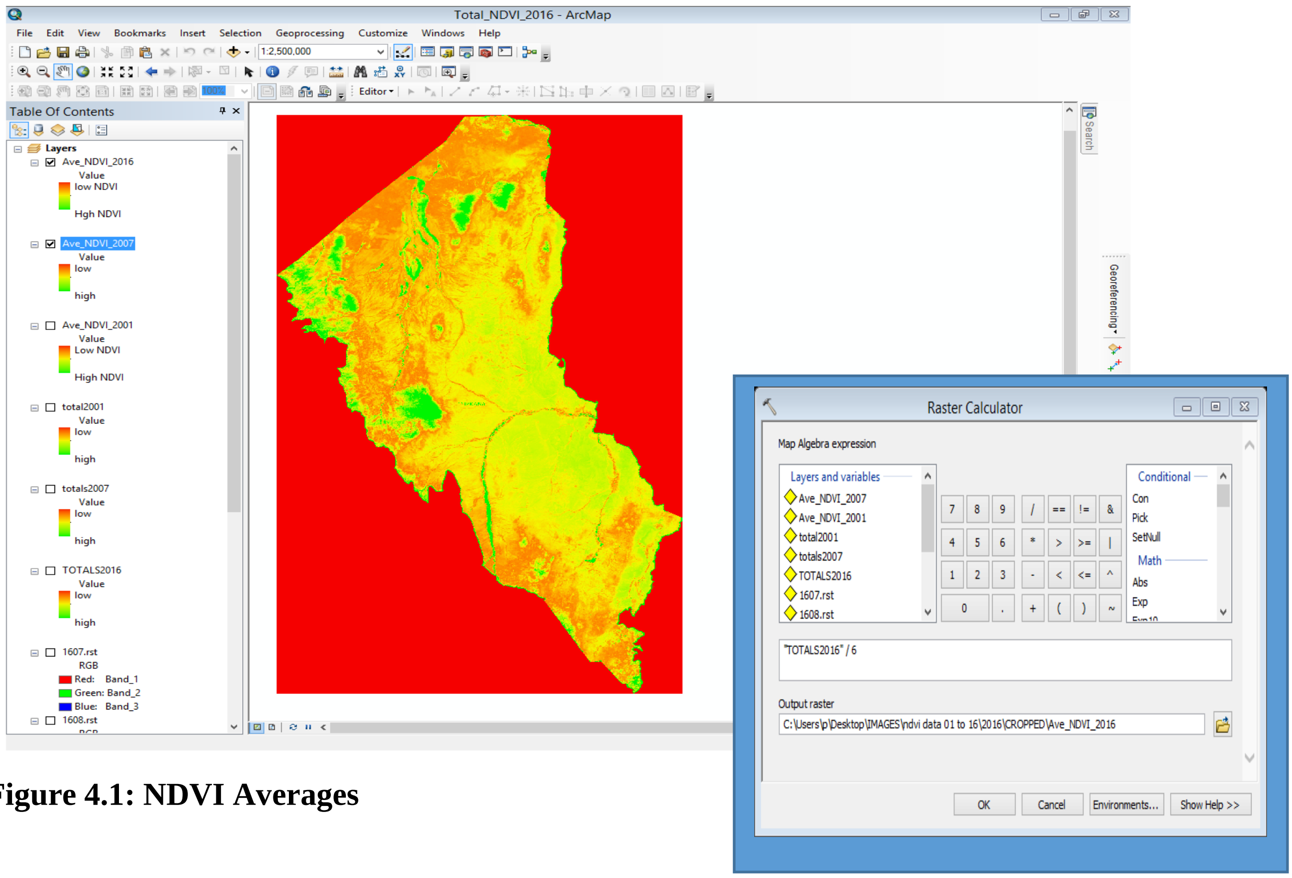


Figure 4.1: NDVI Averages

Figure 4.1 shows a screenshot of the procedure involved in determining the mean of 2016 NDVI.

The following are the results for the selected years.

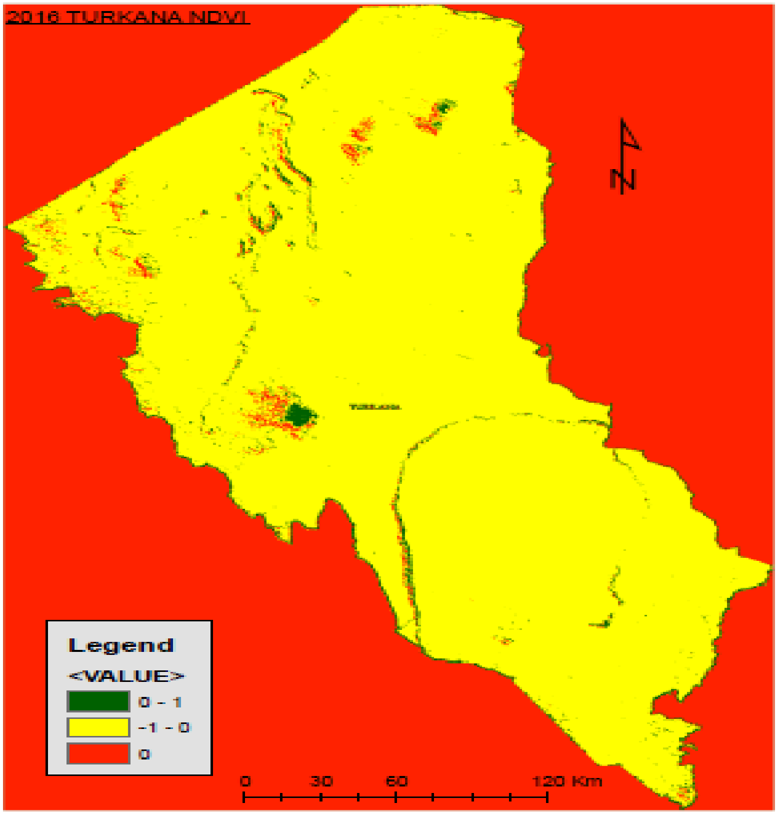


Figure 4.2: 2016 NDVI average map

The fig 4.2 above shows the map of Turkana county patchy areas of green. There is also light green especially in the central parts of the county. There are also brown to light brown areas. This is an indication of variability of NDVI values from positive towards zero and negative one towards zero consecutively. The very green areas therefore tended toward the maximum NDVI value which is positive 1. The reverse is true also for the brown areas which basically represent reflectance from the predominant sandy soil background. The red is the backgroun colour so it signifies no reflectance hence has the value zero in the study.

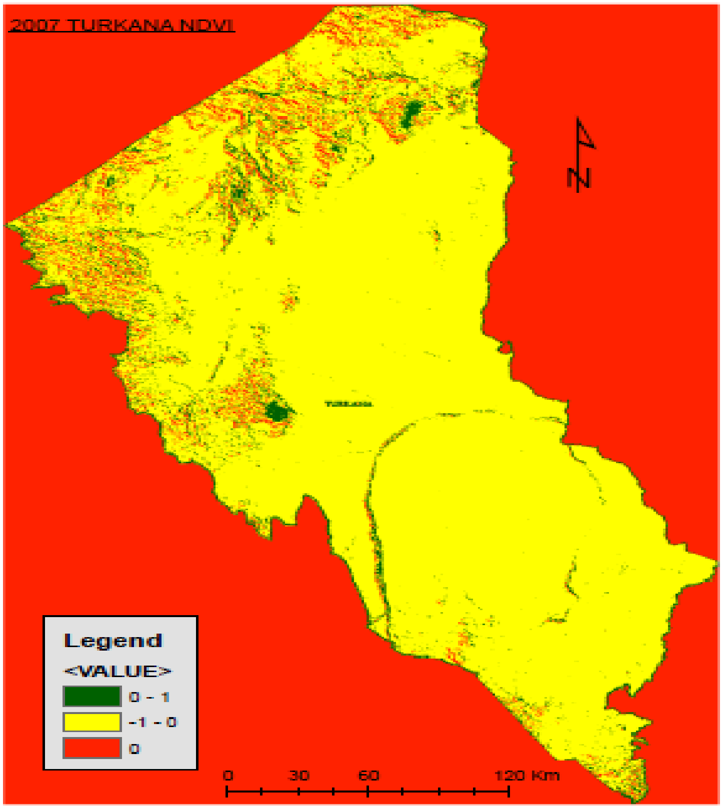


Figure 4.3: Average NDVI for 2007

Fig 4.3 depicting the NDVI map for 2007 employs a similar symbology as fig 4.2. This is for the benefit of easier visual analysis. It is possible to see the green and the brown patches and for this epoch the green is relatively more while the brown is reduced. The 2007 epoch had equal numbers of NDVI maps as 2001 and 2016. The results for instance of the 2016 epoch shows a significant difference from that of 2007. This can be attributed to the events that must have occurred over the time difference. These events had significant effect on vegetation cover which was more pronounced in the northern borders as can be seen.

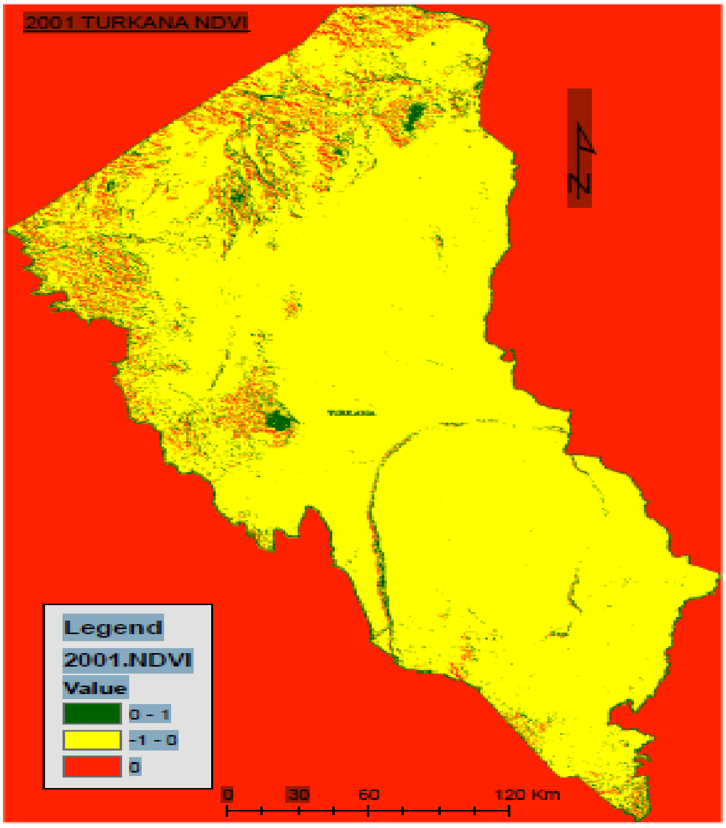


Figure 4.4: representing NDVI for 2001

The fig 4.4 above representing NDVI for 2001 also uses the same symbology and was arrived at in a similar method as the immediate two above. This was also necessary to find a clue of the vegetation cover of Turkana at least an epoch before for trend analysis. It shows a considerably a larger spread of the green parts compared to any of the previous two epochs. This comparison is easier though having the three maps side by side. This was made possible using Idrisi Selva which allows multiple map layout windows. Idrisi is however cumbersome since it allows minimal data formats hence the data had to be first converted to ***.rst*** format using Global Mapper. The results are as shown in the next diagram.

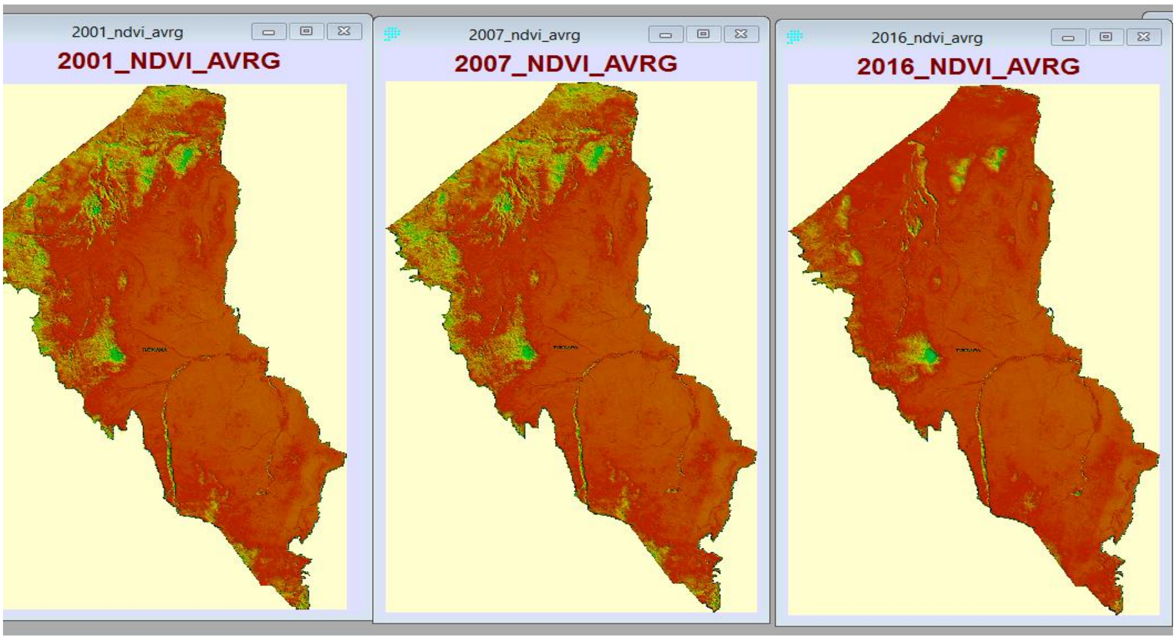


Figure 4.5: NDVI map Averages against each other

Fig 4.5 depicts slight variation between 2001 and 2007 especially in the upper region above the River Turkwel. 2016 map however provides a scientifically interesting situation where the green layer is diminishing significantly

4.3 Rainfall

The rainfall seasons were identified as the MAM and OND as earlier mentioned in this report. The rainfall data for each of the seasons was available in 6 maps for every month and therefore every pixel represented approximately total rainfall for 5 days. This study also relied on epochal data of 10 years starting from 1986 up to date.

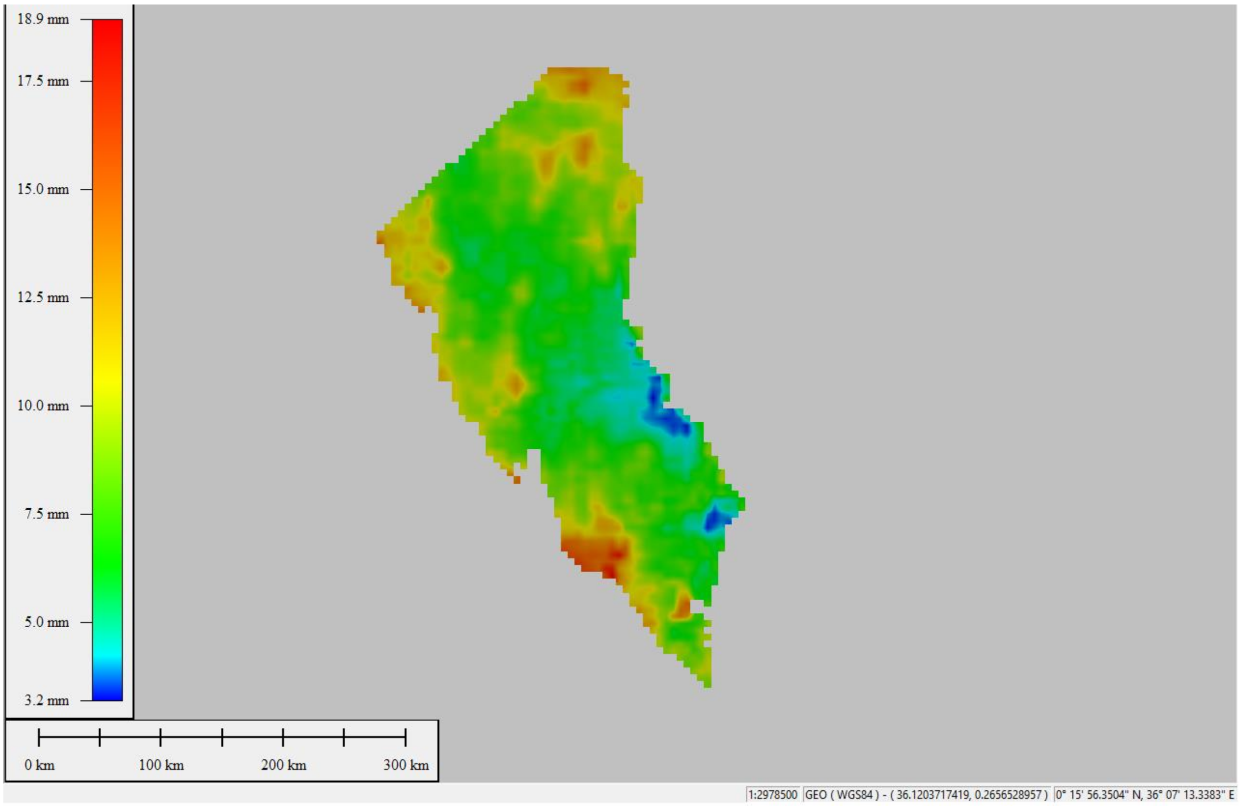


Figure 4.6: 1986 MAM Average

Fig 4.6 shows that in 1986 the maximum recorded rainfall total for 5 days was 18.9 mm and the minimum 3.2mm. The majority of the areas recorded averagely between 5.5 mm and 8 mm of rainfall any 5 days of the year's high rainfall season.

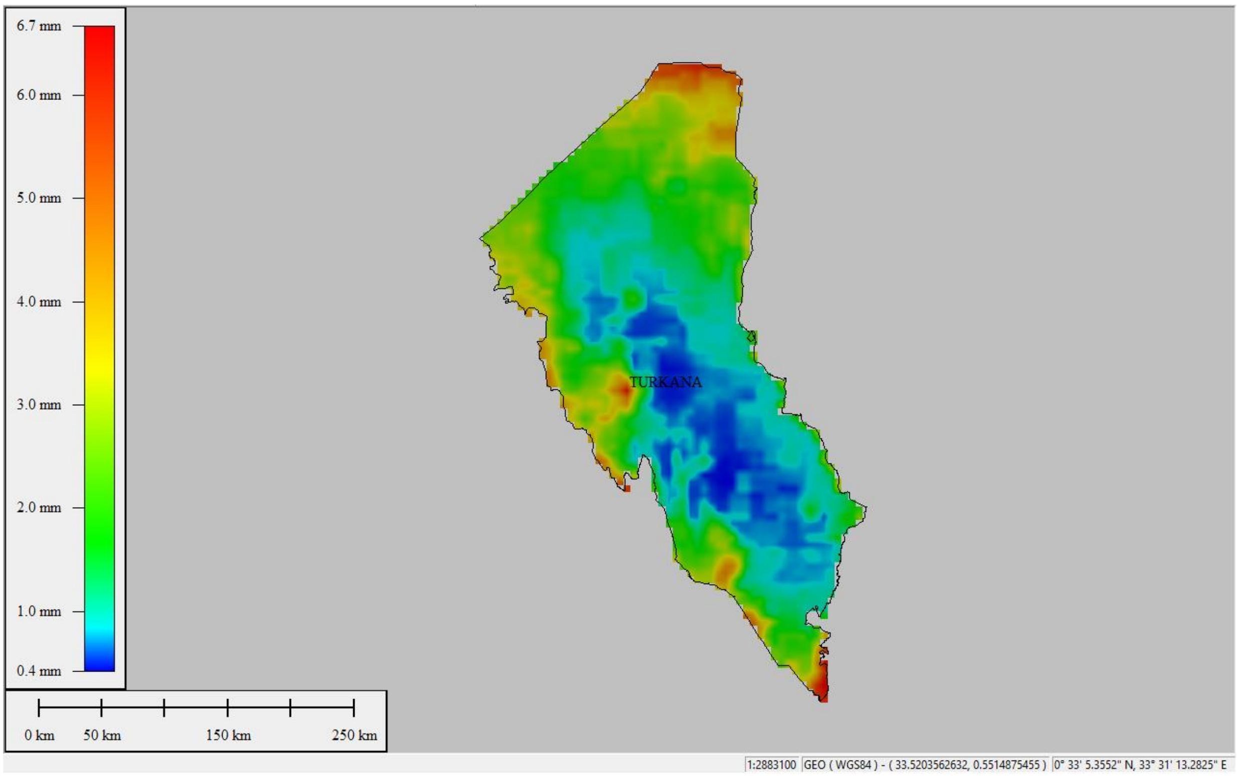


Figure 4.7: 1986 OND Average

The low rainfall season (OND) map for 1986 as shown in fig 4.7 illustrates that large regions especially in the central parts of the Turkana County received five days of rainfall totalling to as low as 0.4 mm. Small parts of the western, northern and southern border regions got the highest rainfall of 6.7 mm for any 5 days of the season. This figure displays an inherent trend as well where the rain gauge values vary incrementally from the central Turkana outwards. Meanwhile it is observable that more than 90 % of the County received way less than 3 mm of rainfall in any 5 days of this season. This would mean that the majority of the people would move with their livestock towards the borders in search of pasture and water.

1996 MAM

1996 series for MAM had 18 different maps of continuous rainfall data similar to all others series considered for the study. The addition and averaging to sample a representative raster was done in ArcMap 10.2.1 and the results displayed in Global Mapper like for all other series. Global Mapper had the added advantage of showing the legend in an elaborate scale bar which is proper for visual analysis. The results for 1996 MAM are as below.

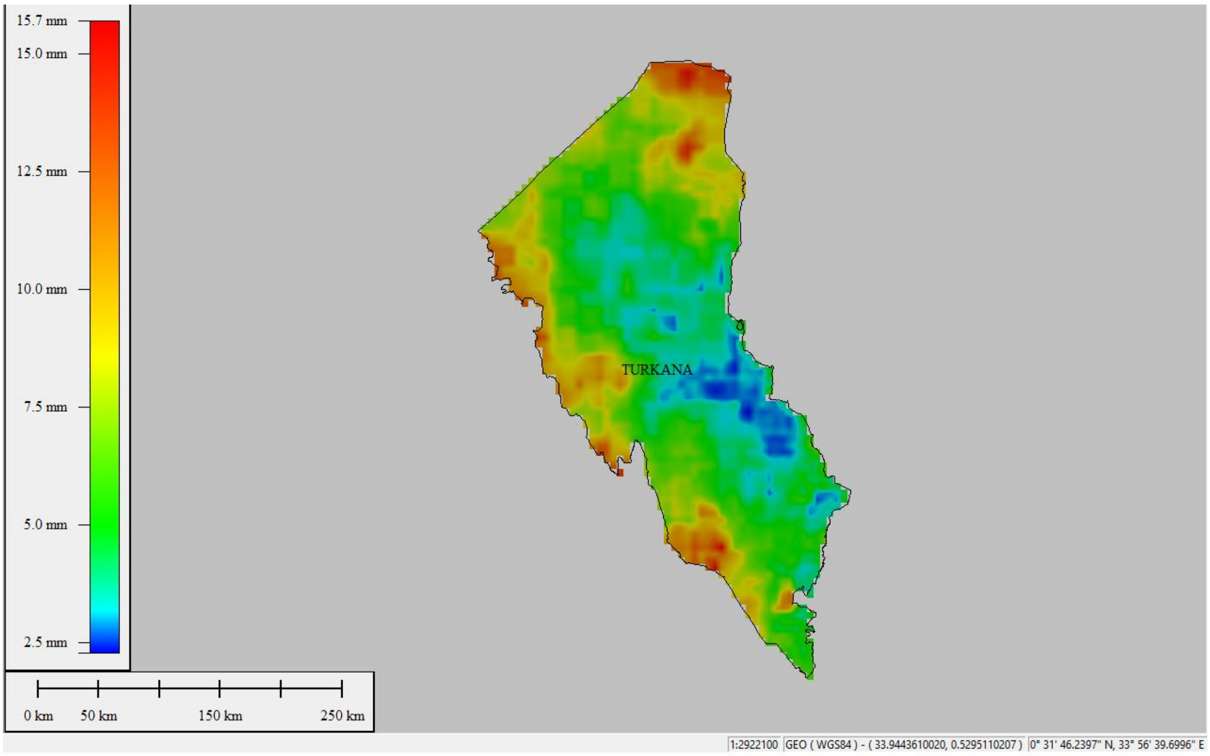


Figure 4.8: 1996 MAM Average

Fig 4.8 shows that in 1996 the highest rainfall recorded for any consecutive 5 days was approximately 15.7 mm whereas the lowest values recordable for the same duration at the high rainfall season was estimated at about 2.3 mm. The same border zones as identified in the 1986 maps received the highest rainfall while the central parts had the least rainfall as most areas had about 5 mm of rainfall.

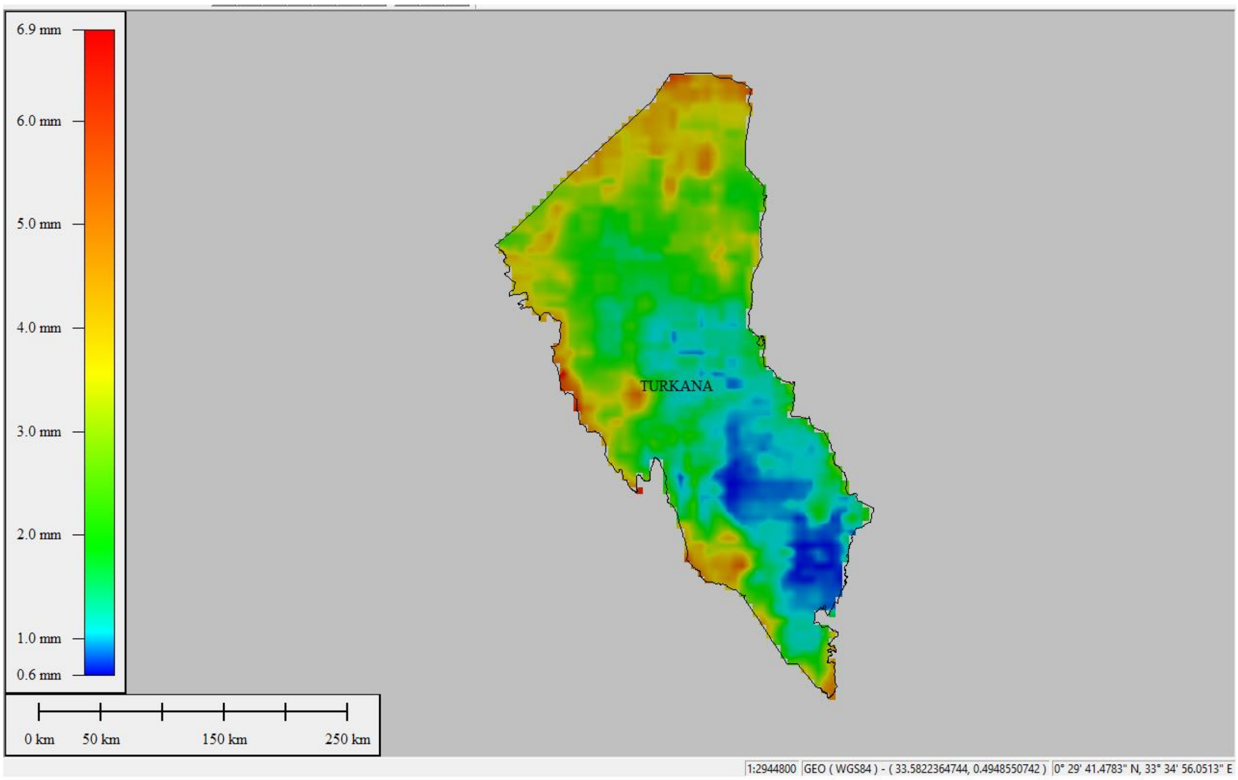


Figure 4.9: 1996 OND Average

The short rainfall season of 1996 is as shown in fig 4.9 indicating a range of 6.9 mm and 0.6 mm of rainfall. This is slightly varied from the OND of 1986 where the minimum is 0.4 and maximum is 6.7. the rainfall trend is also varied with the areas receiving least rainfall tending towards the southern ends compared to the central trend shown in 1986 OND map. The borders towards Uganda and S. Sudan though show similar trend of relatively higher rainfall. Slight parts along the southern borders can also be seen to have recorded rainfall averagely around 5 mm.

2006 MAM

This epoch illustrated variability in weather patterns especially with rainfall recording the highest rainfall value of the epochs considered specifically for the MAM seasons. The results are shown in fig 4.11.

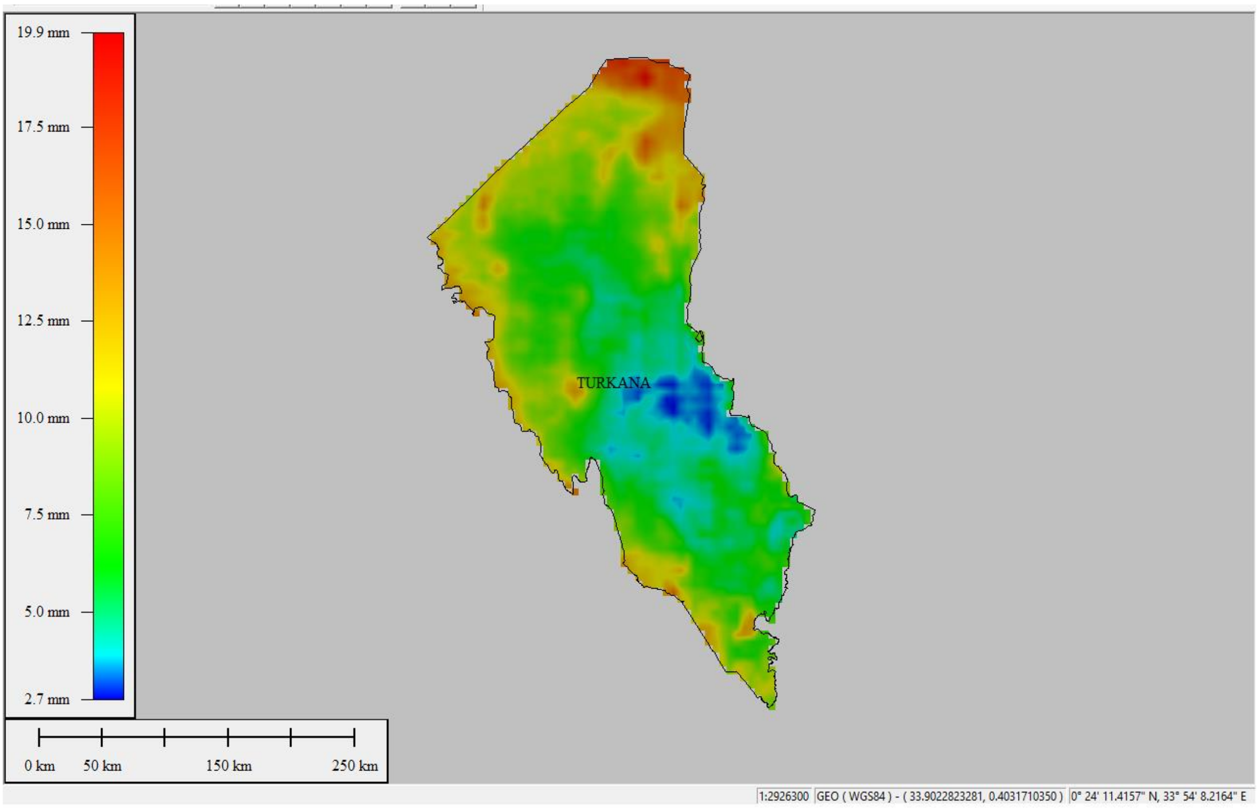


Figure 4.10: 2006 MAM Average

Fig 4.10 above shows that a minimal area in the central Turkana received the least relative rainfall this season which was approximated at 2.7 mm while the widest area recorded about 7.5 mm. The relatively higher rainfall zones received between 15mm and 19.9 mm of rainfall. It is visible in the same map that the northern and western sections were more favoured receiving the largest share of the rainfall recorded for any of the 5 days during the season.

2006 OND

The rainfall variability was also experienced during this season where some areas recorded rainfall values higher than the values from normal high rainfall season over the years.

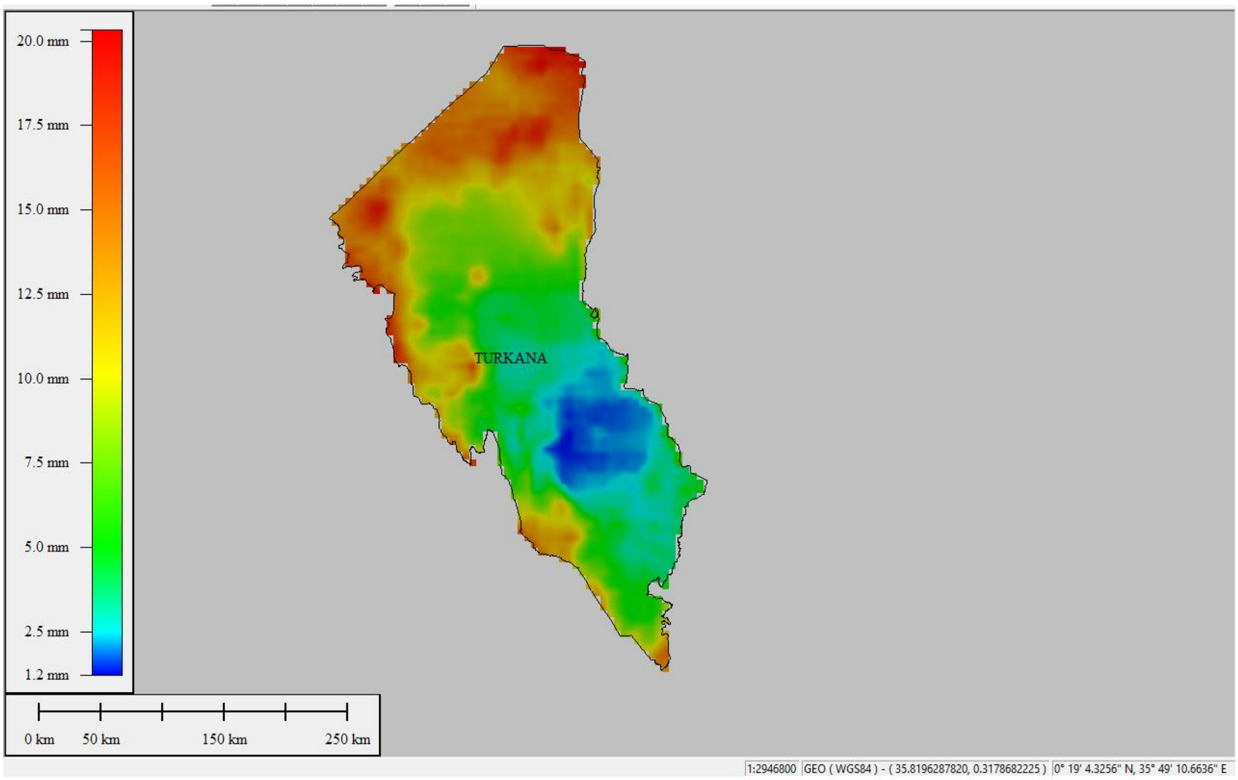


Figure 4.11: 2006 OND Average

Fig 4.11 has a maximum rainfall of 20 mm compared to the 19.9 mm of 2006 MAM season. The minimum rainfall is however lower than the one recorded for MAM the same year. This figure shows a wider area of the northern and north western parts to have received rainfall higher than 15 mm which supersedes the recorded rainfall in most of the seasons as can be seen. 2006 OND values compared to the short rainfall seasons of 1986 and 1996 are totally out of range with over 100% increase in most areas. This is naturally possible considering the fact that people have adopted the idea of tree planting particularly Turkana has had numerous tree species introduced to the ecosystem.

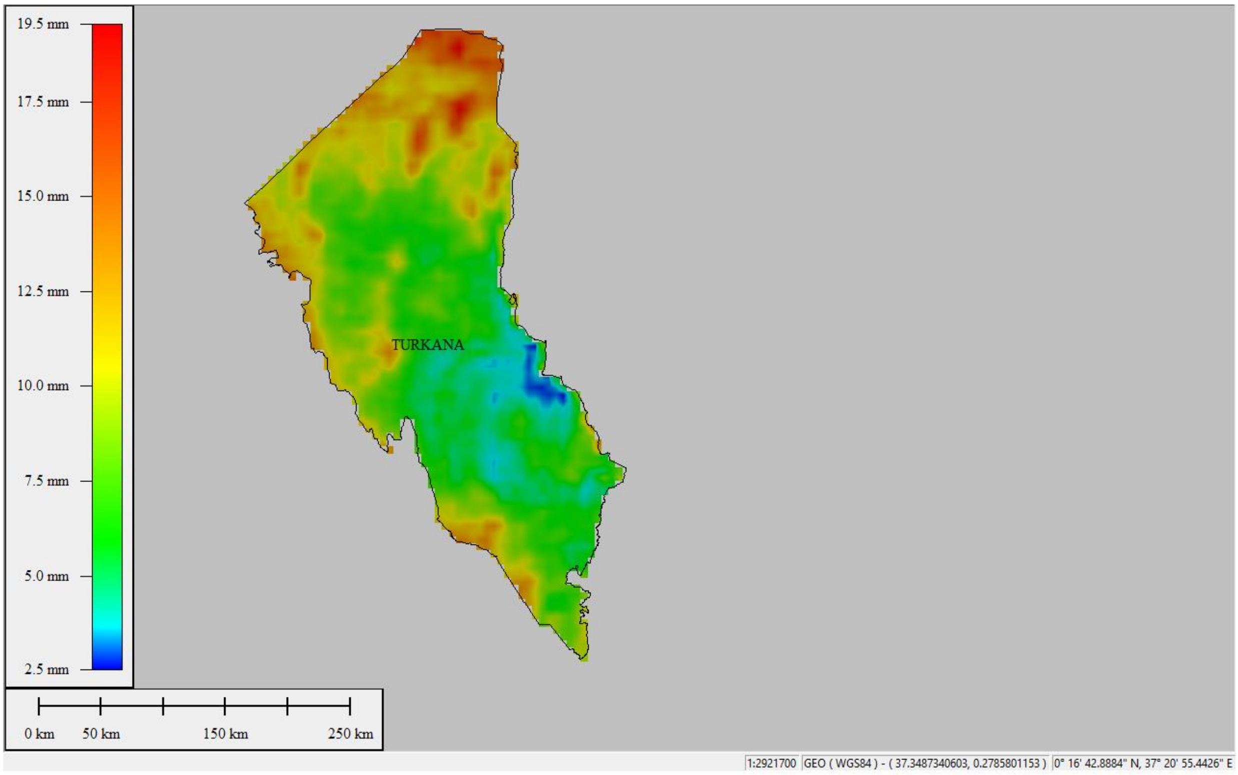


Figure 4.12: 2015 MAM Average

Fig 4.12 is a map of rainfall averages for the high rainfall season (MAM) of the year 2015. The highest rainfall readings recorded for any five days of this season is given as 19.5 mm which is shown to have been in the regions mostly towards the northern borders especially with S. Sudan and partly towards the border with Uganda. The minimum rainfall recorded was 2.5 mm which was experienced in a relatively limited part of the county. Large parts of the county received rainfall of between 5 mm and 10 mm as can also be seen.

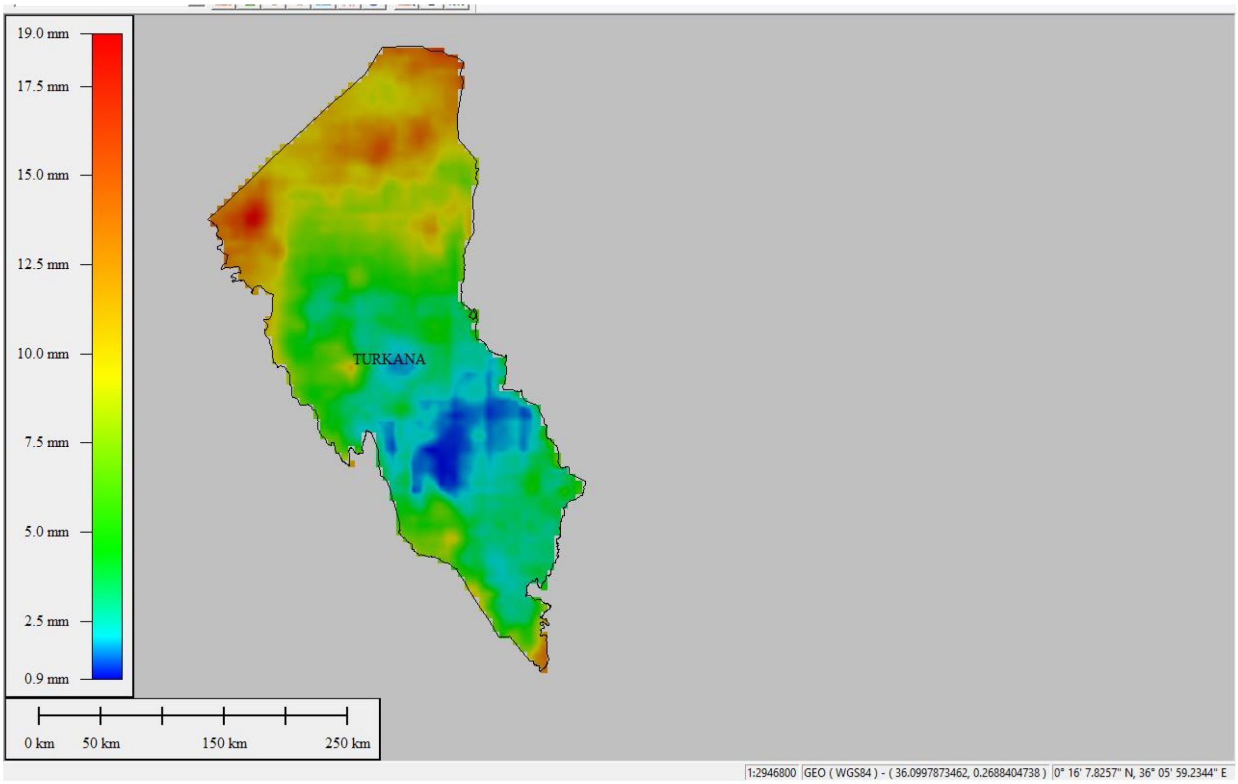


Figure 4.13: 2015 MAM Average

The year 2006 rainfall information for the OND season shows that considerable area around central Turkana received rainfall as low as 0.9 mm in 5 days while comparatively larger areas along the borders with Ethiopia and S. South Sudan had higher rainfall ranging from 15 mm to 19 mm. the rest of the areas received rainfall between 5 and 7.5 mm with minor sections having rainfall of about 10 mm for any of the 5 days over the season.

4.4 Population data processing.

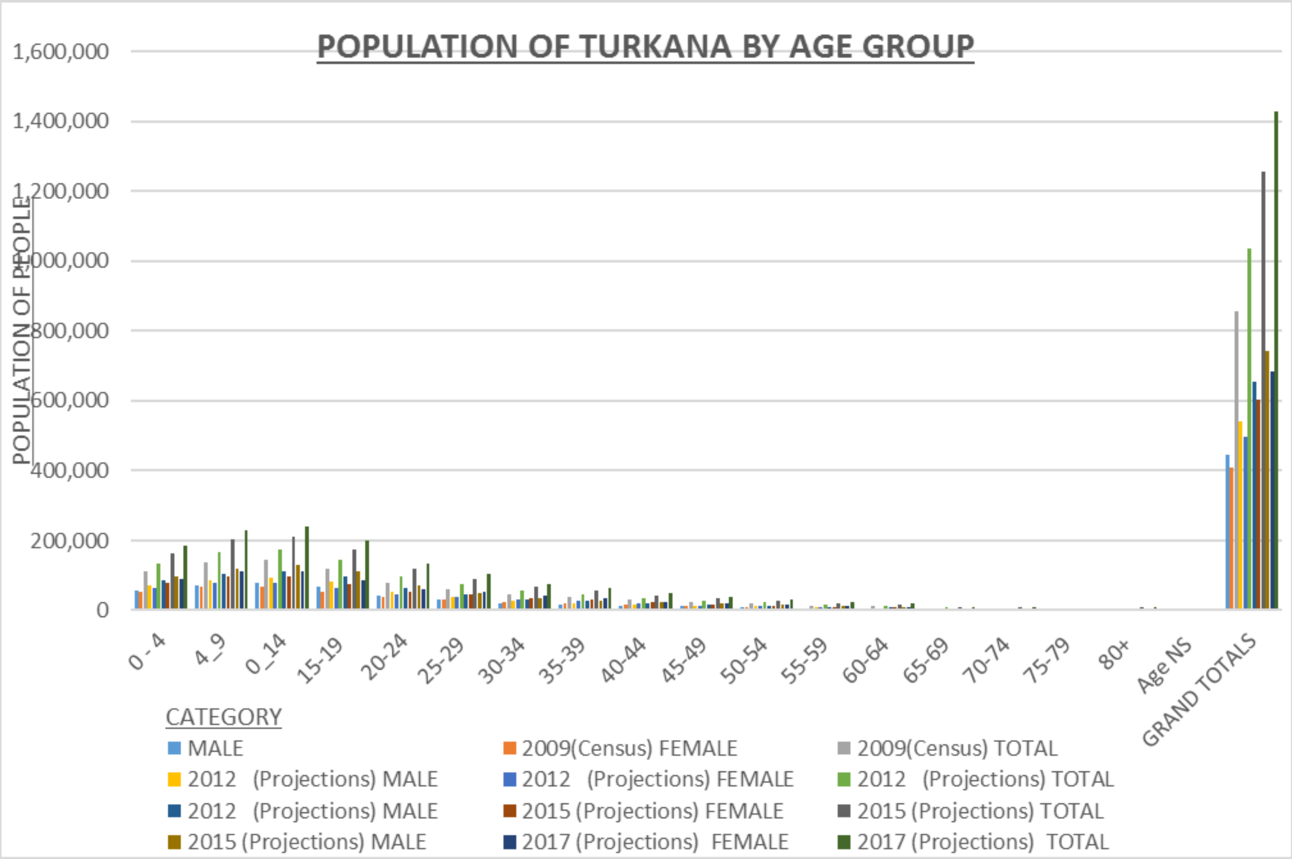
The local population of Turkana rely on food supplies from livestock usually in the form of meat, milk and blood which is supplemented by the local farm produce. They trade among themselves selling their livestock for cash and crops. There are also cattle rustling with the neighbouring communities like the Pokot with whom they interact in their nomadic lifestyle. They are known for sporadic community clashes over shared resources which can only be attributed to inadequacy and lack of insurance against variation and changes in temperature and rainfall, which forms the main source of precipitation.

The community's food availability, accessibility, utilization and system stability is however very unpredictable making it unreliable and insecure for livelihood since the human population tends to be increasing. A large population will cause difficulties considering the lifestyle of the community is nomadic as a way of coping with the climatic changes. The table 4.1 shows the population data of Turkana with projections indicating larger populations should be expected in the future.

Table 4.1: Turkana County population

AGE GROUP	**2009 CENSUS**			**2012 PROJECTIONS**			**2015 PROJECTIONS**			**2017 PROJECTIONS**		
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
0 - 4	57,530	**54,049**	111,579	69,716	65,497	135,213	84,483	79,371	163,854	96,027	90,216	186,243
4_9	**71,898**	66,175	138,073	87,127	80,192	167,319	105,582	97,178	202,760	120,009	110,457	230,466
0_14	77,156	66,405	143,561	93,499	80,471	173,970	113,303	97,516	210,819	128,786	110,841	239,626
15-19	66,881	52,307	119,188	81,047	63,386	144,434	98,215	76,813	175,027	111,635	87,309	198,944
20-24	43,110	37,149	80,259	52,241	45,018	97,259	63,307	54,553	117,860	71,957	62,008	133,965
25-29	30,703	30,850	61,553	37,206	37,385	74,591	45,087	45,303	90,390	51,248	51,494	102,742
30-34	21,742	24,234	45,976	26,347	29,367	55,714	31,928	35,588	67,516	36,291	40,450	76,741
35-39	17,473	21,423	38,896	21,174	25,961	47,135	25,659	31,460	57,119	29,165	35,758	64,924
40-44	14,240	15,130	29,370	17,256	18,335	35,591	20,911	22,218	43,130	23,769	25,254	49,023
45-49	11,584	11,644	23,228	14,038	14,110	28,148	17,011	17,099	34,110	19,336	19,436	38,771
50-54	9,211	9,137	18,348	11,162	11,072	22,234	13,526	13,418	26,944	15,375	15,251	30,626
55-59	6,892	6,823	13,715	8,352	8,268	16,620	10,121	10,020	20,140	11,504	11,389	22,893
60-64	6,010	5,436	11,446	7,283	6,587	13,870	8,826	7,983	16,808	10,032	9,074	19,105
65-69	3,419	3,129	6,548	4,143	3,792	7,935	5,021	4,595	9,616	5,707	5,223	10,930
70-74	2,771	2,349	5,120	3,358	2,847	6,204	4,069	3,450	7,519	4,625	3,921	8,546
75-79	1,470	1,390	2,860	1,781	1,684	3,466	2,159	2,041	4,200	2,454	2,320	4,774
80+	2,741	2,530	5,271	3,322	3,066	6,387	4,025	3,715	7,740	4,575	4,223	8,798
Age NS	238	170	408	288	206	494	350	250	599	397	284	681
GRAND TOTALS	**445,069**	**410,330**	**855,399**	**539,342**	**497,244**	**1,036,586**	**653,583**	**602,569**	**1,256,152**	**742,891**	**684,906**	**1,427,797**

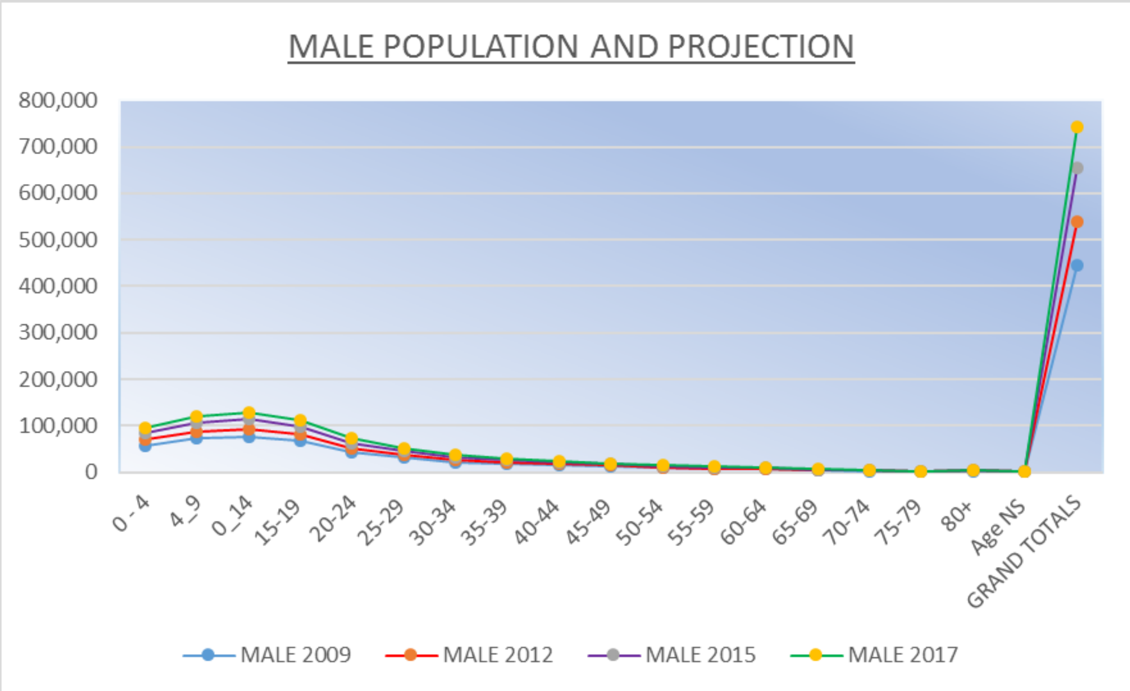
Chart. 1. Turkana County population by age group



All the graphs show that the largest population is between 0 to 20 years. This population then begins to indicate a gradually declining trend from 20 all the way to 80+ age bracket. The total population is consequently projected to increase for every subset of the data.

Turkana Male population maintains an increasing trend across all the age groups as projected for the years 2012, 2015 and 2017. This is likely to apply into the future if all factors remain constant. Chart 2 displays the male population against age group. The line colours represent the specific year.

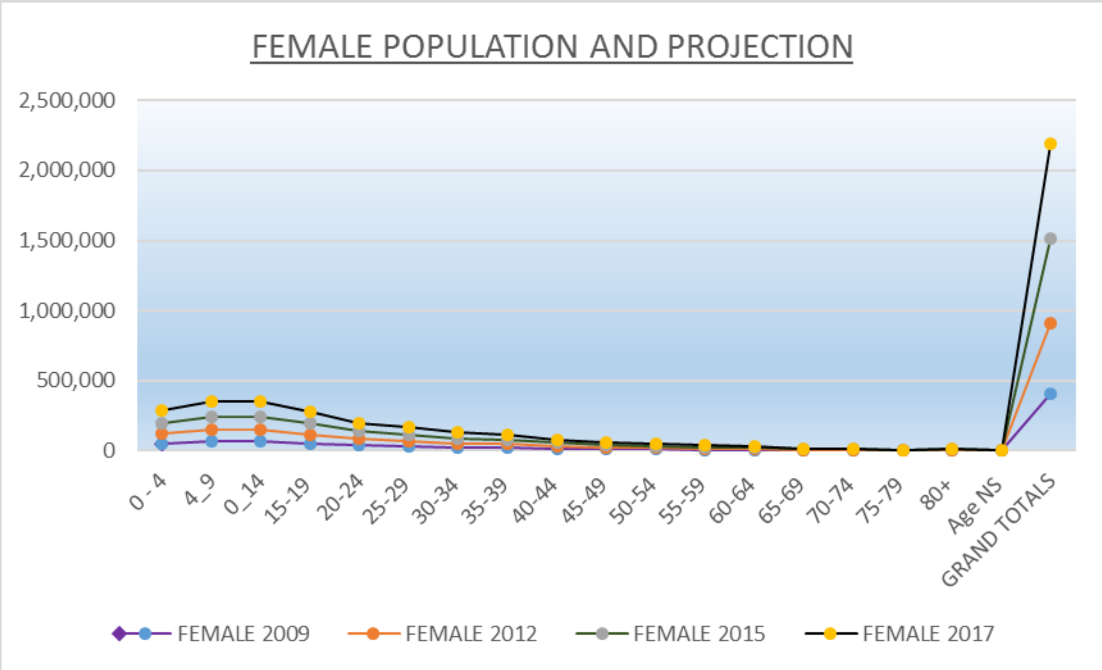
Chart. 2. Turkana County Male Population and its Projection



The male population for all the age groups increase by the year since the 2009 graph is shown to have the least values for all the age groups as 2017 has the highest values followed by 2015 the 2012 in chart 3 above. This is clear the male population is forecast to increase across the age groups.

The Female population adopts a similar trend to that of their male counterpart. It is notable however, that the male population supersedes the female population for the younger age groups. This changes from the age of 30 to 49 years when the women outnumber men. Men above 50 years seem to be more than women suggesting a lower life expectancy for women. The graph of the female population and population projections shown below illustrates an upward trend suggesting larger populations of women in the future.

Chart. 3. Turkana County Female population and its projection



The grand total for the two population categories considered consequently has a rising trend. It is clear from the statistics that between the year 2009 and 2017 the population of Turkana is expected to increase by more than 50%. In 2009 male alone were approximately 445,069 in 2017 this is projected to be 742,891 which is about 67% increase. Female as at the 2009 census 410,330 which is projected to rise to 684,906 giving a percentage increase of 66.92.

Poverty

It is noted that 25% of this population lives in the urban areas with the majority of the entire population falling within the poverty level. In fact, evidence shows that Turkana recorded a Poverty level of at least 87% as per the Kenya National Bureau of Statistics (KNBS) and the Society for International Development (SID) 2013 reports.

4.5 Food Security Status

Climatic extremes, particularly recurrent drought hazards have resulted in depletion of water and pasture resources which are critical for pastoral production systems in the rangelands (Schilling et al. 2012). The incidences of severe, recurrent droughts seem to be on the increase resulting in deaths of large numbers of livestock, resource based conflicts, livestock diseases outbreaks and environmental degradation. In addition to drought, other important risk include human population pressure and settlements, land use changes and exploitation of key resources, disease outbreaks, raids and conflict are all restricting access to critical livestock grazing areas in the arid and semi-arid lands (ASALs) of Kenya. Such are taking place under the backdrop of inadequate infrastructure, poor market linkages, and inaccessible institutions. As a result, pastoralists are likely to be more exposed to the effect of climate variability and change. This will result in a loss of the quality of the productive asset which is livestock undermining the food security status of pastoral communities in Turkana.

4. 6 Results Analysis

4.6.1 The Seasonal Rainfall

This information can be organized and analysed as shown in the **table 4.2** and **chart 4** below. This information is generated from the legends as provided in the previous chapter

Table 4.2: A Summary of the MAM and the OND for the Epochs

		YEAR			
		1986	1996	2006	2015
MAM	MAX Rainfall	18.9	15.7	19.9	19.5
	MIN Rainfall	3.2	2.5	2.7	2.5
OND	MAX Rainfall	6.7	6.9	20	19
	MIN Rainfall	0.4	0.6	1.2	0.9

Chart. 4. Average Seasonal Rainfall Variation

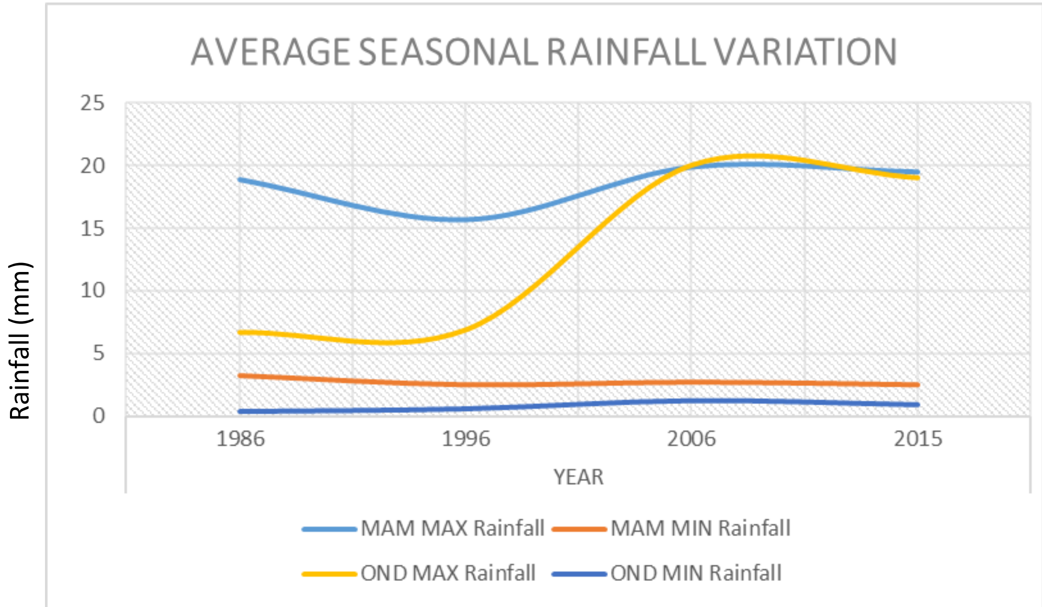


Chart 5 elaborates the trend in the seasonal rainfall of Turkana as captured in table 4.3. The eminent trend is that of the OND rains increasing in certain regions to imitate the amounts received during the MAM seasons. This is a good trend, however, over the same period OND rains are barely felt in some parts of the county as shown by the deep blue curve at the bottom. The MAM rains depict a curve trending between 20 mm and 15 mm for areas that receive the highest rainfall relatively. Meanwhile other areas still receive rainfall estimated at 2.5 mm for 5 days during the high rainfall season. The seasons that fall in between the two are dry hence the little water received is supposed to sustain the vegetation and livelihoods to the next rainfall season.

The rainfall values are so low and given the background soil is predominantly sand it is infiltrated immediately. This may not be supportive for the growth of grass that is required for pasture and that also makes watering the animals difficult. The pastoralists therefore have a tendency to migrate with their animals towards the borders where the land is raised and the rainfall is fairly high. These border zones experience prevalent community conflicts resulting in cattle rustling and inter community warfare which has been known between the Karamojong of Uganda and the Turkana, likewise the pokot of West Pokot and the Turkana, among others.

4.6.2 Livestock as Livelihood in Turkana

The county is subdivided into 6 livelihood zones according to various previous researches. The Central (TCP) and the Border (TBP) livelihood zones which are spatially the largest as shown by the brown and green shades in the map are 80% reliant on livestock. People living in the Central zone keep majorly camels due to less pasture, while the Border zone keep cattle, donkeys, camel, goats and sheep. Agro pastoralist zones supplement livestock with up to 45% dietary support from agriculture. These areas are however limited to the riverine areas of Turkwel and the Kerio. Meanwhile only a quarter of the population lives in the urban areas where they still rear livestock alongside provision of unskilled and semi-skilled labour for the majority as they work in shops, restaurants, public transport or the mines among others.

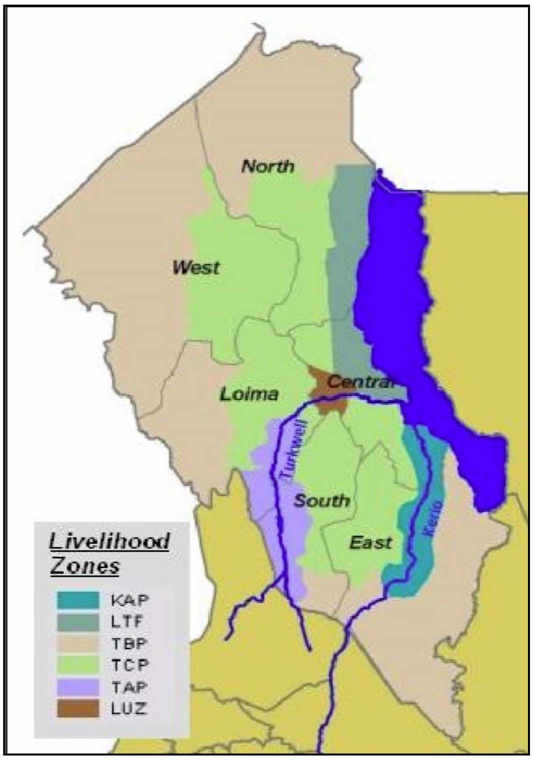


Figure 4.14: Livelihood zones in Turkana courtesy of FEG

The livelihood zones are given as follows:

1. **Central Pastoralist livelihood zone (TCP)** – It is the driest zone and more than 79% of the population here rely on pastoralism alone. The people therefore find it necessary to constantly migrate with their animals in search of pasture and water. This migration is usually outwards especially towards the borders.
2. **Border pastoralist livelihood zone** (TBP) – which lies along the Ethiopia, South Sudan and Uganda borders with Turkana. This constitutes the raised grounds and its extent continues on the southern ends to the borders with Baringo and west Pokot counties. This zone is prone to community conflicts usually involving the shared resources like water points and grazing lands or cattle rustling.
3. **Kerio Riverine Agro Pastoralist livelihood zone (KAP)** - This zone gets moisture from the river Kerio and the Lake Turkana which it borders to the East. The people living here practice mostly subsistence agriculture in small scales to supplement their diet as they also keep livestock. The area is however affected by the unpredictable community conflicts with the Pokot from the South.
4. **Turkwel Riverine Agro Pastoralist livelihood zone (TAP)** – this zone lies along the river Turkwel where there is irrigation practice alongside livestock rearing. The southern ends just like the river Kerio regions are affected by community conflicts and constant cattle rustling mostly involving the Pokot from West Pokot to the South.
5. **Lake Fishing Livelihood Zone (LTF)** –The area does not have large settlement as the authorities encourage protection of the riparian zone while it only stretches about 2 km into the mainland. Fishing is still practiced but not in large scale since even the fish processing plant that was set up in this area has since stalled.
6. **Urban livelihood zone** (**LUZ**) –The zone is predominantly reliant on labour provision for livelihood. This labour is provided in service provision for example in; shops, restaurants, sales of wares, mining stones among others. The majority also keep animals on the side.

The Turkana community has limited sources of livelihood, as it is conclusive from the zoning, which makes them vulnerable especially given that the county is in the ASALs. Livestock rearing is inherent in every zone while the grass is also under threat by some of the introduced tree species like the invasive Prosopis juliflora. The rangelands are therefore overgrazed while the population of the community is also expected to increase over time which means more pressure on the resources**.**

4.6.3 NDVI analysis

Vegetation cover is usually related to the weather conditions of an area especially precipitation. It follows that the more the rains the larger the vegetation cover. NDVI has been used to determine vegetation cover and studies also show that it is a reliable indicator of climatic variables like rainfall, temperature, and evapotranspiration (Gray and Tapley 1985, Anyamba and Tucker 2001). Healthy green vegetation normally has the highest positive values while surfaces without vegetation, such as bare soil, water, snow, ice or clouds usually have low NDVI values that are near zero. These NDVI values range from –1 to +1. Figure 4.8 shows a time series analysis of Turkana NDVI for the years 2001, 2007 and 2016. The vegetation is represented in varying shades of green whereas the bare soil is brick red. 2001 and 2007 have a fairly considerable amount of green which is way too low in the 2016 map.

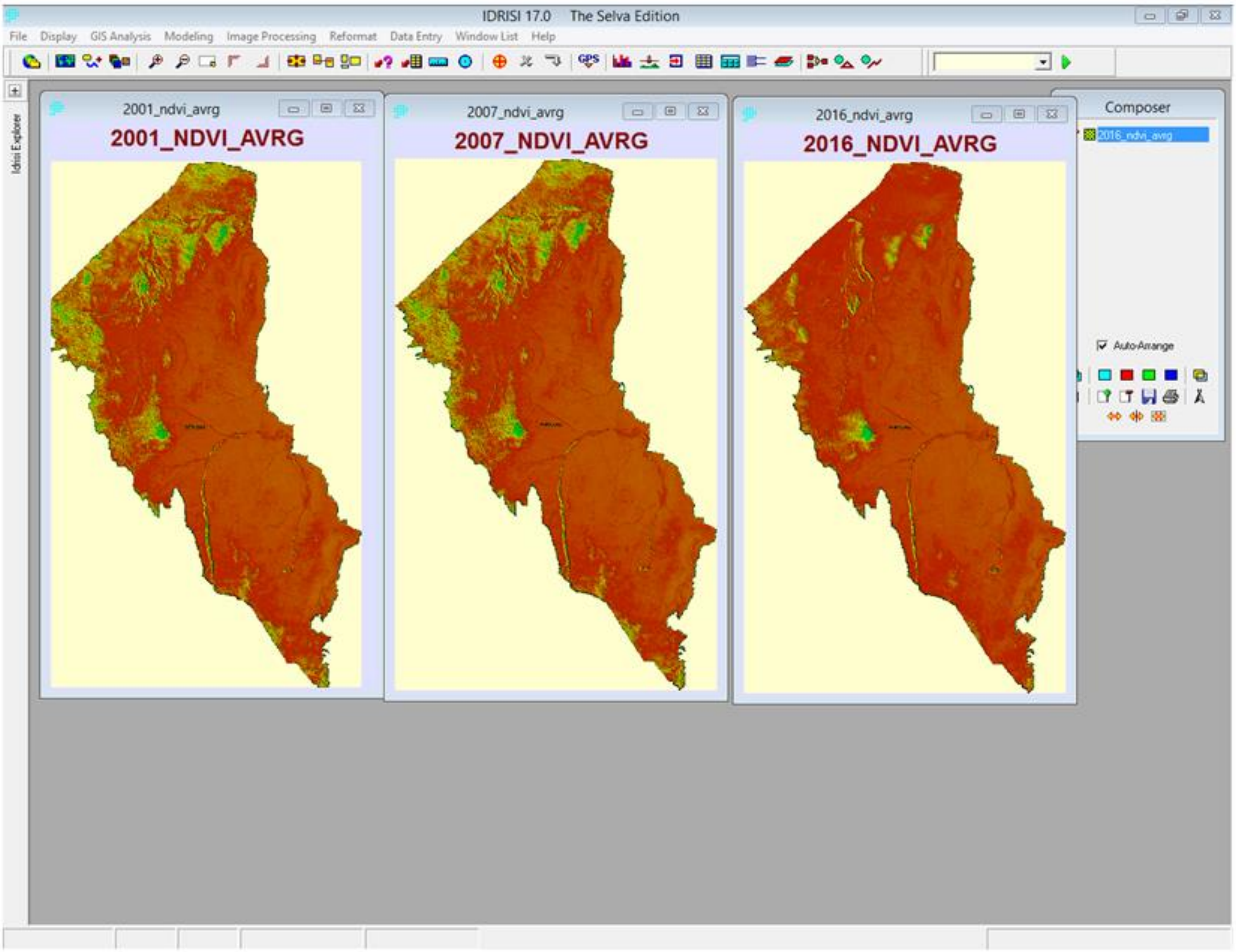


Figure 4.15: Time Series of Turkana NDVI

Principal Component Analysis of NDVI maps

The NDVI maps were done for series analysis considering 2001 and 2007 then 2007 and 2016. The software analysis in ArcMap 10.2.1 is shown and the covariance matrix and the Eigen values obtained as below.

Data file produced by PRINCOMP

Input raster(s):

ave_ndvi_2016

The number of components =1

Output raster(s) =__1000001

COVARIANCE MATRIX

```
#    Layer            1            2
#  -----------------------------------------------------------------------------
       1        1558.87457    1073.63066
       2        1073.63066     979.50176
#
=============================================================
=========
#                   CORRELATION MATRIX

#    Layer            1            2
#  -----------------------------------------------------------------------------
       1           1.00000       0.86885
       2           0.86885       1.00000
#
=============================================================
=========
#                EIGENVALUES AND EIGENVECTORS

# Number of Input Layers        Number of Principal Component Layers
          2                                        1
# PC Layer            1
# Eigenvalues
               2381.21379
# Eigenvectors
# Input Layer
```

1 0.79388

#

==

==========

PERCENT AND ACCUMULATIVE EIGENVALUES

# PC Layer	Eigenvalues	Percent of Eigenvalues	Accumulative of Eigenvalues
1	2381.21379	100.0000	100.0000

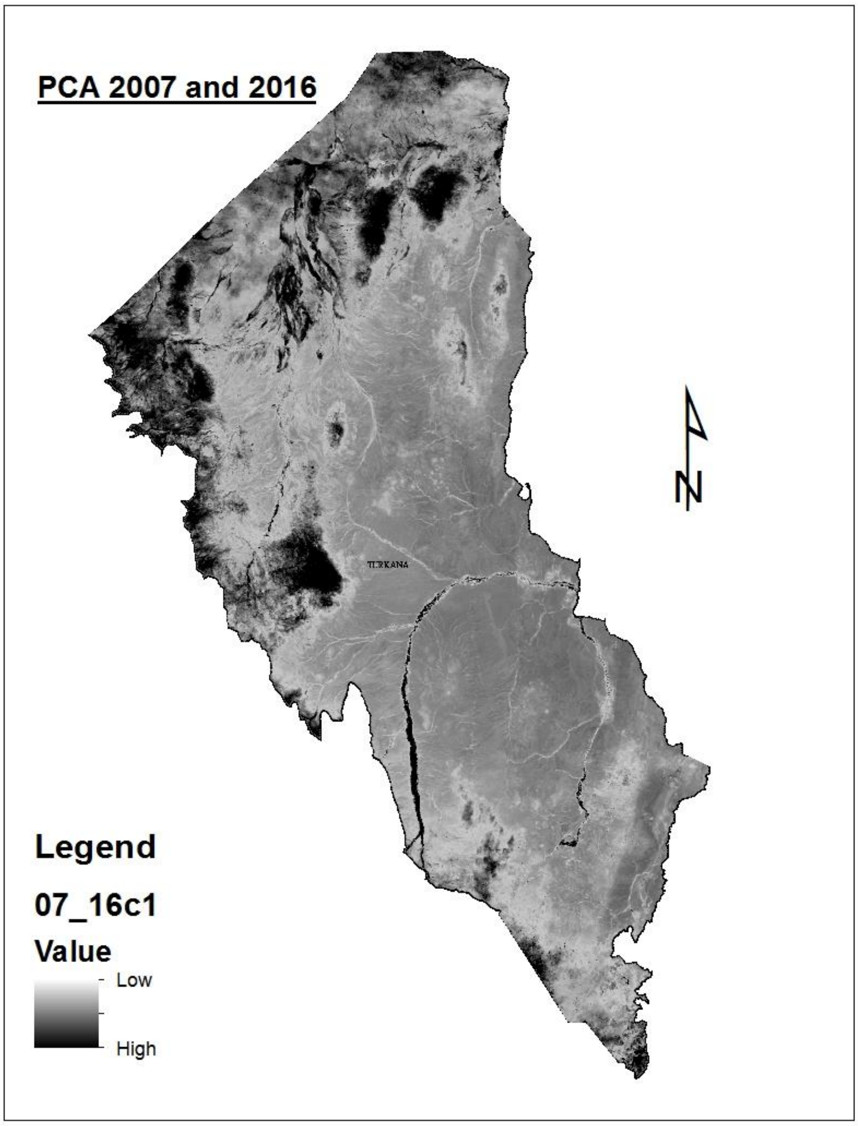


Figure 4.16: PCA for 2016 NDVI against 2007 NDVI

The PCA for 2001 and 2007 is also given as follows;

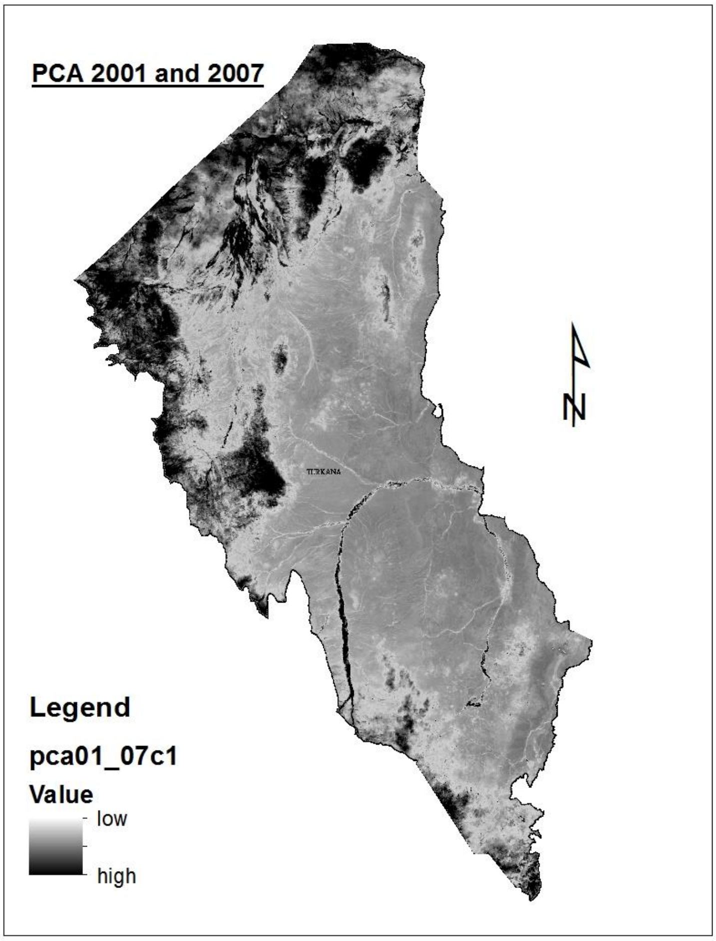


Figure 4.17: PCA for 2001 NDVI against 2007 NDVI

Data file produced by PRINCOMP

Input raster(s):

ave_ndvi_2007

The number of components =1

Output raster(s) =__1000001

COVARIANCE MATRIX

Layer 1 2

--

```
     1        1558.87457    1558.87457

     2        1558.87457    1558.87457

#  ================================================

#                    CORRELATION MATRIX

#    Layer             1              2

#  -----------------------------------------------------------------------

     1           1.00000       1.00000

     2           1.00000       1.00000

#  ==================================================

#                 EIGENVALUES AND EIGENVECTORS

# Number of Input Layers     Number of Principal Component Layers

          2                          1

# PC Layer             1

#  -----------------------------------------------------------------------

# Eigenvalues

                 3117.74914

# Eigenvectors

# Input Layer

     1           0.70711

#======================================================================
=====

#                 PERCENT AND ACCUMULATIVE EIGENVALUES

# PC Layer   Eigenvalues   Percent of Eigenvalues   Accumulative of Eigenvalues

     1           3117.74914              100.0000                        100.0000
```

#==
====

Both visual and software analysis of the NDVI show a pattern of reducing green vegetation cover. This could be attributed to the consumption rate by the livestock being higher than the growth rate which is dependent on the precipitation. NDVI is used as indicator of drought where declining trend in the NDVI is seen as an advancing drought. Predictably there is likely to be less future vegetation cover for Turkana County unless adaptive measures are put in place to counter the eminent trend.

4.7 Discussions

The communities living in Turkana have to cope with the effects of climate change and variability which in most cases include drought and inadequacy of water, epidemics, food scarcity and conflicts over the available resources. This makes it difficult to overcome poverty since there is little access to basic services and the county's state of the infrastructure is poor. It is in fact estimated that over 87% of the county's population survive way below the predetermined absolute poverty line. The majority of this population are traditionally nomadic pastoralists that is a coping mechanism to negative impacts of climatic change but still expose them to other attributed problems like inter community clashes over the shared resources in a bid to survive.

Previous researches assert that Turkana has suffered increased severity of prolonged droughts in the recent past decades which could be attributed to adverse changes in rainfall and temperatures in the Horn of Africa (Nicholson, 2014). This has caused greater uncertainty in the sustainability of the livelihoods in Turkana since the people largely rely on the natural resources like pasture and water whose amounts are directly influenced by rainfall. The findings of this study show the dwindling trend of rainfall with certain areas receiving less than 10 mm of 5 days' total rainfall which would then be followed by a long dry spell until the next rainfall season. The population meanwhile is growing fast and as can be predicted from the lifestyle of the Turkana community a large number of the upcoming generation are likely to take up pastoralism as their economic activity hence increase in livestock population which may mean increased demand for pasture, increased migration, more disease outbreaks and inter community conflicts, unending cattle rustling among many other negative circumstances that may retain generations in a vicious cycle of poverty.

The practice of irrigation agriculture among the Turkana along the riparian of both the Kerio and Turkwel rivers may point to a conclusion that the people can no longer rely on the rains or the traditional livestock keeping solely since the climatic conditions are unfavorable. Previous researches in Turkana also confirm that it is getting considerably difficult for most of the people to recuperate from the inconsistent weather patterns affecting their livelihoods, and many have therefore been forced to consider other coping mechanisms that only increase the cycle of vulnerability (Thornton et al. 2006a; Kabubo-Mariara 2009).

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has revealed that arid and semi-arid areas of Turkana are typified by high rainfall variability and uncertainty with episodic occurrence of uncharacteristic extreme droughts associated with changing climatic conditions.

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

i. The study revealed large variability and unpredictability of monthly and annual rainfall with no significant trend patterns Turkana. However, the result reinforces earlier observations that year to year, season to season variability is persistent in the arid environment of Kenya.

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

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

5.2 Recommendations

Local development programming objectively for long-term resilience is recommended to caution the Turkana community from the adverse effects of climate change and variability. The findings observed could guide various decision makers in Turkana to see, on a local scale, what temperature and rainfall changes are being observed and to help them better plan for a changing climate. This study did not establish the causes of differences in trend and means for seasonal temperature trends; this could probably be investigated further with the aid of an appropriate model. However, it suggests further research into the underlying local factors influencing the climate of the area, causes for the differences in monthly mean temperature, actual effects of ENSO on rainfall totals and the influence of Indian Ocean over northern Kenya. At the same time aspects of the impacts of changing land use patterns, degradation and global warming on the micro-temperature also require more consideration in future research.

Finally, it’s the recommendation of this study that there be the establishment of an information system to provide and support the Turkana community with information on early warning signs to objectively improve resilience to the effects of climate variability and change.

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