ASSESSMENT OF IMPACTS OF CLIMATE CHANGE AND VARIABILITY
ON FOOD SECURITY IN WEST POKOT COUNTY, KENYA

BY

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DECLARATION

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

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DEDICATION

I dedicate this thesis to my parents, brother Philip and my husband Isaiah.
I am greatly indebted to my supervisors Dr. Obade and Dr. Koske for their honest guidance and constructive criticism during the course of this research work. They have left an indelible impression on my mind which will continue to influence my work in future.

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ACRONYMS AND ABBREVIATIONS

AEZ – Agro Ecological Zone
CC – Climate Change
CV – Climate Variability
EOS – End of Season
FAO – Food and Agricultural Organization
FEWS – Famine Early Warning Systems
GPS – Global Positioning Systems
HH – House Hold
IPCC – Intergovernmental Panel for Climate Change
LULC – Land use land cover
KARI – Kenya Agricultural Research Institute
KVDA – Kerio Valley Development Authority
MOA – Ministry of Agriculture
MOH – Ministry of Health
NDVI – Normalized Differential Vegetation Index
SOS – Start of season
UNICEF – United Nations Children’s Fund
WMO – World Meteorological Organisation
WPC – West Pokot County
WRMA – Water Resource Management Authority
ABSTRACT

There is an increasing need for food security assessment in the wake of today’s challenge of climate change and variability. This study aimed at assessing the impacts of climate change and variability on food security in West Pokot County for the period 1980-2012. Objectives of the study were to: characterize rainfall and temperature data for the specified years, evaluate spatial variability in relation to climate change and variability in the county using remote sensing and Geographic Information System (GIS), study the phenology of agricultural vegetation of the area and assess the perception of the household on the relationship between climate variability and food insecurity across three agro-ecological zones in West Pokot County. Household survey, key informant interviews, analyzing rainfall and temperature data and GIS methodologies were adopted. Questionnaires were administered to 124 randomly selected households. LANDSAT and SPOT images were satellite images selected due to their high spatial resolution. The result revealed high inter-annual rainfall variability. The mean rainfall was 973.4 mm p.a. for the years 1980-2011. Years 1984 and 2000 experienced the lowest precipitation of 631.6 mm and 619 mm respectively. Lowlands’ temperatures have increased by 1.25°C and the highlands by 1.29°C respectively over the study period. Majority of respondents strongly believe (68%) that climate variability has occurred in the area with the lowland experiencing a great effect on crop production (75%) followed by the mid potential zone (27%) and finally the highlands (14%). Land cover land use changes showed that cropland has increased by 68% while grassland has reduced by 6%. The mean Normalized Differential Vegetation Index (NDVI) values ranged from 0.36-0.54. There has been a consistent increase in vegetation greenness in the three agroecological zones for the period 2000-2011. The year 2000 was the lowest in greenness and the peak was in 2011 followed by a decrease in 2012 due to the respective decrease in rainfall. The NDVI time series result show on average low values from January to February (0.36) and then afterwards increases and reaches a peak in June (0.54) before it starts decreasing up to September. April and August are the peak rainfall months in the study locations, May and September are the peak NDVI months. Thus, after rainfall onset, there is a one month lag period for NDVI to reach its peak. In the analysis of variance to show the relationship between rainfall and NDVI value when p<0.05 is significant, results showed that changes in NDVI values are not brought about by rainfall only as indicated by the resulting P=0.219. The study recommends integration of indigenous households’ perceptions of climate variability and change with scientific meteorological data on rainfall and temperature trends for better planning and targeting of interventions. It also calls for better adaptation interventions rather than increase in cropland area. Further, it encourages the use of GIS and remote sensing incorporated with survey methods to enable understand events that are inaccessible, yet significant in regards to food security for informed decisions and early warning purposes.
CHAPTER ONE: INTRODUCTION

1.0 Background of the Problem

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change stated that Africa is one of the most vulnerable continents to climate change and climate variability (IPCC, 2007). Among the climate parameters that have exhibited a shift in both short and long-term trends are rainfall and temperatures (Opole, 2013). Previous assessments (IPCC, 1998; Hulme, 1996) concluded that over dependence on rain-fed agriculture and unpredictable temperatures are among the contributing factors to food insecurity. Already, in the Sub-Saharan Africa, climate change has drastically reduced agricultural production through extreme weather events, such as recurrent droughts and floods (Hassan and Nhachena, 2008; Deressa et al., 2008). Elsewhere, in Kenya, frequent droughts and floods have not only claimed lives but have also decimated livestock and reduced farm output (GOK, 2007; USAID, 2007).

Climate variability (CV) means deviations in the mean state of climate statistics and inconsistencies (e.g., temperature and precipitation extremes), on all temporal and spatial scales beyond those of individual weather events, including short-term fluctuations that happen from year to year (Ziervogel, et al., 2006). Food security on the other hand refers to access to sufficient, safe and nutritious food which meets peoples’ dietary needs and food preferences for an active and healthy life (World Food Summit, 1996). According to the World Food Summit, food security reinforces the multidimensional nature of food security and includes food access, availability, food use and stability. 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). Variability in climate decreases crop yields (Lobell and Field, 2007). Olesen and Bindi (2002) noted that the factors of radiation, temperature and rainfall all affect yield to some degree with rainfall, especially affecting the growth and production of the plant (Cantelaub and
Terres, 2004). Variability in rainfall from year to year is closely intertwined with crop yields (Lobell and Field, 2007).

Increasing climate variability is something the world cannot avoid to ignore. Specifically, in Kenya there is a strong sense that more should be done to make the Kenyan society better prepared for future climate variability incidences. The reported 0.7–2.0°C increase in temperature during the last 40 years in Kenya, together with irregular and unpredictable rainfall, has increased water-scarcity problems, alongside degradation of catchment areas and lakes (Mutimba et al., 2010). The growth rates in crop yields have been significantly declining and the ongoing climate change is forecasted to reduce crop yields even further in many parts of the world (Braun, 2007; Pingali, 2012) thus affecting food security.

West Pokot County is one of the food deficient and food insecure Counties in Kenya (GOK, 2007). The increasingly arid conditions in the county are generally viewed as impact of climate variability. The county is situated where extremes of climate variation such as drought and unpredictable rainfall patterns, coupled with famine and related humanitarian disasters, are being experienced.

Moreover, WPC has a diversity of agro-ecozones, all affected differently by climate variability impacts. The vast majority of Kenyan climate change research has focused on the arid and semi-arid lands (ASALs) in general, where rainfall is “always” a constraint on productivity and pastoralism (Jones et al., 2009). In contrast, the medium and high potential agro-ecozones also targeted by this study support the bulk of the Kenyan population. These zones are also subject to climatic changes that means agricultural production can be constrained by water scarcity, soil fertility, or flooding even over small temporal and spatial scales (Notter, 2007).

Given an existing context of substantial variability and uncertainty in most Kenyan production systems (e.g. of rainfall, temperature, crop-soil systems and markets), it is important to deepen the understanding of how longer term trends of climate variability
are understood and portrayed in local knowledge (Roncoli, 2006). This study focused on local perceptions on CV in three AEZs with regard to food security. The study also provides trends in rainfall and temperature variability. Phenology studies for plant growth observation gave an understanding of climate variability and growth periods of the predominant crops grown in WPC i.e. maize, beans, cabbage and carrots.

The objective of this study was designed to assess the impacts of climate change and variability on food security in West Pokot County, Kenya. The study analysed rainfall and temperature trends spanning the period between 1980-2012 and evaluated spatial variability in relation to climate variation in the county using remote sensing and Geographic Information System techniques for the years 1984, 1990, 2000 and 2010. It also studied the phenology of agricultural vegetation in the area for the years 2000-2012 as well as assessed the perception of the household on the relationship between food insecurity and climate variability in the area.

1.1 Problem statement

Recent research has focused on regional and national assessments of the potential effects of climate change on agriculture (Hassan and Nhachena, 2008). In addition, 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 (Hinkel, 2011). These efforts have treated each region or nation in general without relating to changes in food production in other specific local places (ODI, 2007). 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 favour of ecosystem-scale studies of biophysical vulnerability. In fact, an understanding of vulnerability to climate variability and change and food security is needed at the level that would specifically address specific geographic location so that the communities will get adequate lessons to tackle climate
change challenges with the precision that is necessary (Klein, 2004). To address this evident gap, this research in West Pokot County coordinated effort needed in research to provide for continent-wide climate monitoring including the specific local places.

A weakness identified in previous research in climate change in Africa (and Kenya specifically) however is that, despite the complexity of likely transformations and outcomes of climate variability, there is lack of validation of local knowledge and perceptions (SPORE, 2008 and BNRCC, 2008) or local perceptions are noted only in terms of ‘‘awareness’’ of climate change (Gbetibouo, 2009). However, it is acknowledged that policy interventions to support local communities dealing with large or unknown climate change risks must engage rural peoples’ varied and context-specific attitudes towards the relationship between climate variability and food insecurity in order to come up with best ways to manage the risks (Doss et al., 2008). Accordingly, there is the need to gain as much information as possible, and learn the positions of rural farmers, their perceptions on climate variability and food security and their needs, about what they know about climate variability, in order to offer adaptation practices that meet these needs in future. This current research attempted to fill some of the gaps with a nuanced understanding of the relationship between climate variability and food insecurity, emerging directly from the knowledge and experience of WPC community.

An important premise behind this study is that, while we are not yet in a position to focus on how climate may change (either on the short or on long term) we can estimate the potential consequences of each of a number of possible climate changes. By considering the range of impacts on food security in WPC we can improve both on our techniques of impact analysis and armory of potential responses. Thus at some point in future, when we are able to make reasonably accurate forecast of climate change, we shall also have acquired an ability both to assess their impact and to respond effectively to them. Coe (2011) states that, the starting point for understanding the effect of future climate variables needs understanding of the current
situation. The above author emphasizes that we have the tools. Hence, more effort is needed to make the data available, build climate analysis into every agricultural project and bring relevant and accurate climate information to farmers.

1.2 Research questions

The research questions that formed the basis of this study were:

1. What is the spatial variability in relation to climate change and variability in West Pokot County?
2. How has temperature and rainfall been changing in West Pokot County between 1980 -2012?
3. What is the phenology of agricultural vegetation in West Pokot County?
4. Do households associate food insecurity with climate variability?

1.3 Research objectives

The main objective of the study was:

1. To assess the effects of impacts of climate change and variability (temperature and rainfall) on food security with focus on agricultural vegetation

Specific objectives

The subsidiary objectives that contribute to this main objective were:

1. To evaluate spatial variability in relation to climate variation in the county using remote sensing and Geographic Information System techniques
2. To characterize annual and seasonal rainfall and temperature from 1980 -2012 in West Pokot County
3. To study the phenology of agricultural vegetation in the area
4. To assess the perception of the household on the relationship between food insecurity and climate variability in the area
1.4 Justification

The ongoing debates on climate change and food security by the scientific community importantly gives rainfall and temperature variability and reliability a considerable attention at different scales. Climate projections suggest that variability is likely to increase in the future and extreme weather events might become more frequent in sub-Saharan Africa (IPCC, 2012; Omondi et al., 2013). However, the effects, risks and uncertainty with the science around the subject of climate change and projections are daunting, challenging and complex to understand at different levels (Omondi, 2014). This justifies that the subject of climate change and variability is one of the most controversial in the entire science of meteorology and climatology at present (Kalumba et al., 2013).

Understanding dimensions of monthly, annual, seasonal rainfall and temperature is an important part of research studies helping to clarify climate change discourses and its effects on the natural behaviour of ecosystems and arid systems (Omondi, 2014) as well as effects on food security. There is also noted paucity of information on the responses of vegetation to precipitation anomalies, especially for non-equilibrium rangelands of Kenya (Omondi, 2014). An improved understanding of vegetation sensitivity to precipitation anomalies and corresponding temporal reaction patterns at a more local scale is therefore critical for these arid and semi-arid ecosystems. In the recent years, time-series studies of rainfall and temperature patterns and environments have been carried out at various spatial (e.g. regional, national) scales using various statistical procedures (Wagesho et al., 2013). Yet, very few have considered rainfall and temperature data as climate parameters in their analysis using GIS and remote sensing to analyse trends at spatial and temporal scales and the resultant impacts on food security.

There are few detailed work on rainfall and temperature trends using observed climate records in the ASALS of Kenya (Omondi, 2014). Hitherto, limited scientific studies
have focused on spatial and temporal analysis of climatic parameters at micro-scale in the arid and semi-arid environment of West Pokot. Yet, this region in the recent past has experienced extreme weather events and micro climatic variability reported to have had huge influence on ecosystem dynamics and human welfare especially in these environments (Herrero et al., 2010). Understanding climate trends and magnitude is critical to mitigate the adverse impacts of climate change and variability, and would guide communities to make strategic, long-term decisions that affect their future well-being. Therefore by studying the trends and changes in the rainfall and temperature with a simple yet direct approach, the results hope to show how policymakers and the communities can better prepare for natural extremes and reduce the loss of life and property.

1.5 Conceptual and theoretical framework

The conceptual model presented below (Figure 1.1) depicts the linkage between climatic variability with food security. Climate change and variability is highly notable through changes in normal rainfall trends and temperature variations (Olmos, 2001). Predictions are that more powerful and more frequent droughts and storms will wreak greater devastation. Rising sea levels will ruin fertile farmland. Changing rainfall patterns will deplete harvests (Tyler et al., 2013).

Hitherto, the major impacts of climate variability on agricultural production are noted to come from changes in temperature and rainfall (Msughter and Ujoh, 2013). The result of crop failure often leads not only to loss of income but also food insecurity. The nature of mankind is to fight for survival so if crops fail to give them enough to eat, they always find other means as alternatives to secure food. These alternatives are called adaptation and coping strategies for food security. Moreover, internalizing past experiences, avoiding repeated failures and innovating to improve performance are all important characteristics of agents that foster resilient systems (Tyler and Moench, 2012).
The widely accepted World Food Summit (1996) definition reinforces the multidimensional nature of food security and includes food access, availability and food use. Specifically, another determinant labeled food stability was put forward as contributing to food security (FAO, 2011; Schmidhuber and Tubiello, 2007), accounting for both short and long-term fluctuations in food supply. For example, this factor would describe the impacts of extreme weather events influencing production, or changes in food production during the growing season, food storage, fluctuating farm revenues and food prices during the non-growing season (Tyler et al., 2013).

Recently, more emphasis has been placed on the spatial and temporal aspects of food security. Notwithstanding, WFP uses Geographical Information Systems (GIS) and innovative satellite applications and to collect manage and analyse data (WFP, 2014). For example, by analysing trends in rainfall patterns and regeneration of vegetation cover, potential bio-physical threats to food security can be identified and monitored over time. Moreover, WFP uses GIS to combine survey data with geographical information to identify the root causes of food insecurity and vulnerability.

GIS is mentioned as one of a preferred monitoring tool using land cover land use scenarios as well as NDVI to study past and current vegetation growth and health. According to Nayak et al. (2001), NDVI provides an opportunity to study vegetation changes overtime. Changing land cover on the other hand alters the sensible and latent heat fluxes that exist within and between the earths’s surface and boundary layers thus influencing land surface-atmosphere interactions, (Yang, 2004). As such, changes in land cover and land use are bound to influence meteorological parameters including precipitation, humidity and temperature and hence affect the Land surface, its properties and activities occurring on it.
Figure 1.1 Conceptual framework showing the relationships between variables in the study
CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

Over 80% of the Kenya landmass falls under arid and semi-arid climate where droughts and floods are the main characteristics (Huho et al., 2010). This makes Kenya prone to climate vagaries. Evidence of climate variation has become more pronounced and characterized by alternating cycles of droughts and floods. This chapter presents a critique of different scholars on climate variability with regard to food security. It shows the gaps the study intends to fill and how its findings forms an important contribution to climate change adaptations, GIS technology use and development issues.

2.1 Climate variability in Kenya

Climate variability is increasingly emerging as one of the most serious global problems affecting many sectors in the world and is considered to be one of the most serious threats to sustainable development with adverse impact on environment, food security, human health, economic activities, natural resources and physical infrastructure (Huq et al., 2006; IPCC, 2007). Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts (IPCC, 2014). Africa is identified as one of the most vulnerable regions to climate variability in the world where Kenya is inclusive and ninety eight percent of the agricultural activities in Kenya are rain-fed (UNEP, 2009). As the backbone of Kenya’s economy, agriculture is very vulnerable to increasing temperatures, droughts and floods, which reduce crop productivity.

In Kenya, droughts and floods are not new phenomena. Their characteristics, intensity, duration and spatial extent vary from one event to the other. The frequency of occurrence and severity of floods and droughts have been increasing over time. For instance, the frequency of drought increased from once in every 10 years in 1970s, to
once in every 5 years in 1980s, once in every 2-3 years in 1990s and yearly since 2000 (Howden, 2009). The alternating cycles of droughts and floods do not only destroy the livelihood sources but also severely undermine the resilience of the people living in the affected areas (KRCS, 2012). In some arid and semi-arid counties, pastoralists have lost more than half of their livestock to droughts in the past ten years with over 60% of the inhabitants living below the poverty line (Grünewald et al., 2006). Today, famine relief due to climate extremes is a regular feature in some parts of the arid and semi-arid counties such as West Pokot.

Climate variability is also noticeable in WPC whereby increase in the frequency of prolonged droughts, increase in the cases of landslides during flood events, changes in river regimes including river courses, e.g. River Suam in Kongelai and Kacheliba had changed its course, changes in temperature, e.g. Lelan’s average temperatures have increased (GOK, 2012). The action plan report also noted reduction of water levels in rivers, e.g. River Weiwei, pasture reduction, floods and siltation of rivers, e.g., River Sigor and R. Sebit, loss of soil to gully and wind erosion and increase in forest fires. The report noticed that the identified impacts have already affected food production leading to increased food insecurity, poverty and even loss of human life as farming is the main source of livelihoods in the county.

Scientific findings show a growing consensus that the world has to grapple with increasingly severe climatic events. Some of the manifestations of climate change are rising average temperatures with the last three decades having got successively warmer (Arndt et al., 2010), increasing sea levels which have been rising at an average 1.8 mm/year between 1961 and 1992 and about 3.1 mm/year since 1993 (IPCC, 2007) and the thinning snow cover in the Northern Hemisphere. In Kenya, studies indicate that temperatures have generally risen throughout the country, primarily near the large water bodies (King’uyu et al., 2000; GoK, 2010). Other projections also indicate increases in mean annual temperature of 1 to 3.5°C by the 2050s (SEI, 2009). This has the potential to inundate agricultural lands and cause food insecurity.
Generally, Kenya’s climate is also expected to warm across all seasons during this century. Under a medium emission scenario, the annual mean surface air temperatures are expected to increase between 3°C and 4°C by 2099, which means it will rise at a rate of 1.5 that of the global average (Boko et al., 2007). The country’s arid and semi-arid lands (ASALs) have already witnessed a reduction in extreme cold temperature occurrences (Kilavi, 2008). This warming has lead to the depletion of glaciers on Mount Kenya (IPCC, 2007; UNEP, 2009). In addition, the rising temperature levels will inevitably lead to higher rates of evapotranspiration, further reducing the impact of rainfall on soil water for crop growth (Boko et al., 2007). As predicted by Boko et al. (2007) this temperature increases are also expected to lead to overall increase in annual rainfall of around 7% over the same period, although this change will not be experienced uniformly across the region or throughout the year. Seasonal rainfall trends are already mentioned to be mixed, with some locations indicating increasing trends while others showing decreases. Moreover, the expected increase in the variability of rainfall and the increase in temperatures are likely to increase the intensity and frequency of extreme weather events in the region, meaning that many areas in East Africa will be faced with an increased risk of longer dry spells and heavier storms with a direct effect to food security.

It is therefore worth mentioning that climatic seasonality and unpredictability causes fluctuations in crop production and contributes to food insecurity. This calls for predictability and vulnerability studies on climate variations to reduce on food fluctuations probabilities especially in the three AEZ of West Pokot through outlining the current and past weather occurrences of the area as per the years specified for early warning purposes

2.2 Impacts of climate variability on crop production

Food especially food crops is a fundamental requirement in our everyday life. The well-being of large populations around the world depends on access, stability and
availability of food (Schmidhuber and Tubiello, 2007). This is especially true in the developing world with predominant small land holders and subsistence farmers for whom the on-farm agriculture and off-farm agricultural labor provides the main source of food and income (Ito and Kurosaki, 2009). Besides, the vulnerability of these smallholder and subsistence farmers is greatly influenced by changes in climate (Morton, 2007). Changes in climate have already decreased crop yields in several regions and are estimated to have reduced global maize production by 12 Mt a year between 1981 and 2002 (Lobell and Field, 2007). For example, in 2003, unusually high temperatures during the summer reduced food production (and killed over 50,000 people in Europe), with cereal and fruit harvests dropping drastically in Europe, especially in Italy and France where maize production fell by more than 30% (Ciais et al., 2005; Battisti and Naylor, 2009).

Generally, the scientific evidence on rainfall variability with its significant impacts on crop yield is now stronger than ever (Hare, 1985; WMO, 2000; IPCC, 2001, 2004; Adejuwon and Odekunle, 2006). One undisputable causes of 'famine' in WPC is the failure of crops resulting from insufficient or untimely rainfall and increasing temperatures. A Nigerian slogan that “rainfall is the husband of maize yield” is worth mentioning at this time. It notifies that rainfall supply is all needed resource for maize yield. As the prime water source, rainfall is considered to be a critical factor that regulates ecosystem production (Tal and Arnon, 2010). The year to year variability of rainfall is a significant constraint to the sustainability of rain-fed farming systems in poorer countries in sub-Saharan Africa (SSA) (Unganai, 2000). Crop simulation models have shown the negative impacts of climate variability on crop growth, especially if it happens at specific crop development stages (Semanov and Porter, 1995). Extreme daily temperatures above a certain threshold may also have damaging consequences on crop yields (Schlenker and Lobell, 2010; Welch et al., 2010).
2.3 Local perceptions on impacts of climate variability on food security

One’s perception depends on one’s environment and its characteristics (Heathcote, 1969). It is in this notion that Weber (2010) believes that most farmers’ knowledge and exposure to climate change has been influenced indirectly by the media from events occurring in distant areas, e.g., the melting of ice sheets in the Antarctica rather than local events. Slegers (2008) also indicated that experience is an important factor that shapes individuals’ perceptions, in terms of seasonality, with previous experiences of poor seasons bringing in memories and being responsible for how farmers may tend to describe different season types and be able to relate with food security. Perception has been described as referring to a range of judgments and attitudes (Slegers, 2008). Bryant et al. (2008) suggests that the farmers’ perceptions on climate change and variability are important in adaptation as they determine decisions in agricultural planning and management by the farmers. As well, documenting how farmers’ frame the conditions they experience is crucial for understanding their responses to said conditions (Roncoli, 2006; Tschakert, 2007) especially for different land potential capacities.

In the climate variability literature, traditional ecological knowledge (Berkes et al., 2000; Folke, 2004), local knowledge and local ecological knowledge (Olsson et al., 2004) are used to refer to the cumulative body of knowledge, practice and belief, that are location-specific, acquired through long-term observation of (and interaction with) the environment, and transferred through oral traditions from generation to generation. Based on the available literature, this current study used local knowledge to mean a cumulative body of knowledge on weather and climate variability and its’ effect on food security in the area (Huho and Kosonei, 2010).

The validity of local knowledge has been shown by scientists through comparison with quantitative climate data analysis (Cabrera et al., 2006). The majority of studies show that farmers’ resourcefulness matches quantitative data analysis: local
knowledge is used to respond to the vagaries of climate such as droughts, famines, floods and other stresses that threaten crops and livestock (Newsham and Thomas, 2011). However, there have also been cases where local knowledge failed to match quantitative climate data, making local knowledge seem unreliable, e.g., as reported from Kenya by Rao et al. (2011). This study will build on other authors who have cross-checked local knowledge with quantitative climate data to ascertain its relevance for climate variability. The study also provided evidence of farmer’s perceptions matching with the existing quantitative historical climate data of the county for the past 30 years (1980-2012).

2.4 Need for phenological studies in climate variability research

Phenology is the science of studying life-cycle events of plants and animals, and their responses to seasonal and inter-annual variation in climate (Morisette et al., 2008). Importantly, the word phenology as derived from Greek means to show, to bring, to light, and make to appear, meaning that this subject mainly focuses on the significant timing of biological events in their annual cycle. Land Surface Phenology (LSP) uses Remotely Sensed (RS) images to track the growth stages of green vegetation (emergence, growth, maturity, and harvest) at both local and global scale (Anyamba and Tucker, 2005).

More than five methods of observing LSP have been developed and widely used: 1) phenological observation networks; 2) phenological modeling; 3) eddy covariance flux towers; 4) global change experiments; and 5) using remotely sensed images (White et al., 2009). Because the timing and events of plant life cycle were obtained from field data, early phenological studies deeply relied on plant observation networks (Hopp, 1974). The current study was interested in using phenology as a means to detect changes in growth cycle of dominantly grown crops in WPC. Arguably, LSP could change because of changing climate, leading to phenomena such as the earlier onset of spring (Myneni et al., 1997; Zhou et al., 2003) or earlier senescence. However, LSP
could also change as a result of shifts in land cover proportions or alterations in land use practices. In this case, land cover/land use changes occurs on many different spatial and temporal scales and also in multiple forms ranging from alterations in crop type to changes in land use category, for example, from cultivated to residential.

The success of phenology at large scale is attributed to the development of remote sensing technology (Goward, 1989). Moulin et al. (1997) compared the traditional method of phenological research (using ground observation records) with new technology (capturing vegetative signals from RS images), and concluded that collecting data from RS technology is more efficient and effective than measuring data on the ground. However for improved accuracy, the two need to complement each other.

2.5 Phenological Methods of studying climate variability in crop growth cycles

The Start of Season and End of Season (SOS/EOS) can be defined as rapid sustained increase/decrease in remotely-sensed greenness after/before the longest annual period of photosynthetic senescence (White et al., 2009). In reality, these measures are thought to represent the process or rapid events like green-up, leaf-out, and leaf-loss. Phenological characteristics are typically calculated by pixel. As a result, it is difficult to select an appropriate method to determine the Start of Season/End of Season (SOS/EOS) of a region by RS image without ground observation. De Beurs and Henebry (2010) divided 12 different methods to determine SOS by using RS images into four categories: thresholds, derivatives, smoothing functions, and fitted models.

Other authors (Lloyd, 1990; Fischer, 1994; Zhou et al., 2003) showed that setting an arbitrary threshold is the simplest way to determine the SOS/EOS in RS images of which the study adopted. Usually the SOS is determined when the annual normalized differential vegetation index (NDVI) curve first arrives at certain value whereas EOS is determined as the day of the year when threshold is reached again in downward direction of the curve.
Normalised Differential Vegetation Index (NDVI) is commonly used to observe vegetation growth and dynamics (Myneni et al., 1997). The performance of NDVI relies on the absorption of energy from red light by chlorophyll and scattering of near infrared energy by green plants. The decrease of red reflectance and increase of near-infrared make NDVI sensitive to canopy fluctuations. It can differentiate between vegetated and non-vegetated pixels within an image and assess whether the observed target contains living green vegetation or not. It is used to evaluate biotic activities on the earth’s surface as well (Lee et al., 2002). The NDVI is calculated from two bands reflectance of a sensor as follows:

$$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})};$$

Where RED and NIR bands represent the spectral reflectance measurements in the red band and near infrared band, respectively. Theoretically, NDVI of a given pixel scales from -1 to +1. The observed NDVI range for a land surface with vegetation is from 0.05 to 0.8. A non-vegetated pixel typically has a value close to 0, and highly vegetative pixels have high positive values. If the values are 1, -1 or below, it corresponds to an area of rocks. NDVI saturates in high biomass.

NDVI has been mentioned of success by several authors from different studies. For example, studies done by Martiny et al. (2005; 2006) proved that NDVI data have been successfully used to understand the spatial and temporal variability of vegetation resources for at least three decades across sub Saharan Africa. Hutchinson (1991) also mentioned that NDVI images have long been used to monitor crop growing conditions over broad regions of semi-arid areas of sub-Saharan Africa. According to Rasmussen et al. (1992), NDVI has also been used to predict crop yields and demonstrating a significant correlation with annual and monthly rainfall totals. Nicholson, et al. (1994) found out that these useful properties of the NDVI have led to its adoption by the Famine Early Warning System (FEWS) as an operator indicator for food monitoring.
This current study explored to express the effect of rainfall intervals on spatial and temporal dynamics of NDVI in WPC. It produced an original analysis of the 2000-2012 NDVI data series from SPOT 5 satellite for WPC to reveal spatial and temporal changes in potential primary productivity. The intrinsic trend was a smooth function that shows the gradual longer-term change in NDVI which is an index of potential primary productivity.

2.5.1 Tools for climate and variability prediction

Previous studies on the impacts of rainfall variability on crop yield made use of only statistical-based technique in their analysis. Among these are the works by Tim (2000); FAO (2001); Chiew (2002); Adejuwon (2004); Adejuwon and Odekunle (2006). GIS offers a mechanism to integrate many scales of data developed in/for agricultural research. Surprisingly, little systematic research has focused on the distribution patterns of the impacts of rainfall variability in terms of mapping the spatio-temporal impact using the GIS equipment. There is no doubt that farmers and Agricultural Agencies increasingly need detailed GIS maps of this kind as a means of Spatial Decision Support System (SDSS) to plan crops planting schemes and to monitor yield rates. Complementing statistics with GIS, remote sensing techniques has been historically used for agricultural applications and have been most fruitful (Uboldi and Chuvieco, 1997). Same authors noted that right from the beginning of the Landsat programme, the potential value of remote sensing data for predicting crop yield have been explored. According to Das (2000), combining local and global resolution sensors, crop inventory have been pursued most effectively on a large scale. Remote sensing therefore offers an economical means of collecting data from which valuable agriculture statistics or agricultural related information can be derived.
CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter describes the study area, design and identifies the nature, type and sources of data obtained. It also presents the description of the techniques, methods of data collection, sampling of the respondents and the statistical tools used for data analysis. To achieve the objectives outlined in 1.3, the methodology employed integrated technologies of remote sensing, GIS for spatial data capture and analysis and statistical method (questionnaires and interviews).

3.1 Study Area

Location: West Pokot County is situated in the former Rift valley Province along Kenya’s Western boundary with Uganda. It lies between latitudes 10° 10'N and 30° 40'N and longitudes 340 50'E and 350 50'E and covers approximately 9,100 square kilometers. Its average elevation is 1674m above sea level. Neighboring counties are: Turkana to the North; Baringo to the South East; Marakwet to the South and Trans-Nzoia to the South West. The county headquarter is located in Kapenguria town which is approximately 435 km from Nairobi by road. The map showing the study area is as shown in Figure 3.1 below.
Climate: WPC has relatively rugged terrain characterized by hills, dry plains and rugged escarpments which influences its climate with the lowlands experiencing arid climates and the highlands experiencing sub humid climates. The county has two rainy seasons i.e. the "long rains" (March – June) and the "short rains" (September – November). Annual rainfall ranges from 700 mm in the lowlands to 1600 mm in the highlands. Temperature ranges from 15°C to 30°C in the lowlands and to as low as 9°C in the highlands. Generally, 80% of the county is arid or semi-arid.
Population: The County is inhabited primarily by the Pokots and has a population of 512,690 people with a density of 56 persons per square kilometer (GoK, 2009). Population distribution is uneven with high settlement densities on the highlands of Lelan and Kapenguria. About 60% of the population live in the lowlands such as Alale, Kacheliba, Chesegon and parts of Sigor division and practice nomadic pastoralism while the rest of the population are agro-pastoralists living in the highlands.

Drainage: The County, which is typically a rangeland, is drained by Rivers Turkwel, Kerio and Nzoia. Rivers Turkwel and Kerio drain northwards into Lake Turkana while River Nzoia drains into the Lake Victoria in the south (Adan and Pkalya, 2005). Ninety five percent of the County is part of Turkwell catchment while the other 5% is part of Kerio catchment. The Suam River is the only perennial stream in the Alale-Kapedo and the Suam-Turkwel sub-catchment areas. All the major and minor tributaries of the Suam River are seasonal. Apart from these, other perennial rivers are Muruny and Weiwei and their tributaries around the Cherangani hills.

Poverty rate: By 2006, poverty level in WPC stood at 69.4%. By 2009, 69.8% of WPC population was poor (GoK, 2009) and the poverty rate in the rural and urban areas registered 53% and 65%, respectively. The highest numbers of the poor are found in the divisions of Kongelai and Alale. High prevalence of poverty is mainly attributed to unreliable weather patterns, unemployment, poor infrastructure and insecurity (cattle rustling). Insecurity deprives the people of their live hoods, leading to abandonment of homesteads and disruption of economic activities, subjecting them to high levels of vulnerability (GOK, 2009).

3.2 Study design

Study sites were selected with regard to the land classification types in West Pokot largely based on food (crop) production potential. According to Hogg (1984), the Pokot themselves utilize their land largely on the basis of altitude, rainfall and
agricultural potential. As noted by the same author, the Pokot have classifies their land into three zones. Briefly, he analyzes the three zones as follows: The *Masop*, or high mountain tops, which receive most of the rain and are heavily forested, the *Kamas*, or steep mountain slopes, and the *Tow*, or flat valley land. Thus, food production in the area corresponds more or less to altitude, soils and climatic conditions.

In this regard, the study classified its interest on high potential zones which are all area in the highlands and corresponds with *Masop*. This area receives the highest amount of precipitation per annum. Most of West Pokot district areas fall in this category. Medium potential was defined by areas adjacent to the highlands and corresponds with *Kamas*. Most of South Pokot district areas fall in this category. Finally, low potential i.e. area far away from the highland and is mostly arid and corresponds with *Tow*. Most of North Pokot district areas fall in this category.

### 3.3 Sampling procedures

Purposive and random sampling was used to select households for the study. The formula used is as shown below:

\[
Sample \ size \ n = \frac{\left( \left( z^2 \times p \times q \right) + ME^2 \right) + \left( ME^2 + z^2 \times p \times q / N \right)}{\left( ME^2 + z^2 \times p \times q / N \right)}
\]

\[
n = \left( \left( \left( 1.96 \right)^2 \times 0.94 \times 0.06 \right) + \left( 0.04 \right)^2 \right) / \left( \left( 0.04 \right)^2 + \left( 1.96 \right)^2 \times 0.94 \times 0.06 \right) / 512690 = 136 \text{ households}
\]

First, West Pokot County was purposively sampled based on the geographical location, diversity in agroecological zones and proneness to drought events. A list of administrative districts in the three land classification types was given from which one district was selected randomly as a representative whereby West Pokot District, South Pokot District and North Pokot District were selected. From the randomly selected districts, the divisions within the county were listed and purposively categorised on the
basis of the land classification in the area, climatic conditions experienced in the specific locations, accessibility/security and the extent to which they were perceived to be prone to extreme climate events whereby one division per district was selected and Kapenguria, Chepareria and Kacheliba were selected. Alale was termed to be more severe in terms of the impacts of climate variability conditions on food security but due to the prevailing insecurity conditions, Kacheliba was selected instead following the similarity in climatic conditions. Further 20 locations from the divisions were randomly selected. Finally, the total number of households was obtained from the Kenya National Bureau of Statistics records for the area. A random start was used in choosing the first household to be interviewed.

3.4 Instruments

The study used survey method whereby it administered both open and closed questionnaires to farmers. It also used GIS images from SPOT 5 and Landsat for past evidences.

3.5 Data collection procedure

The study used both primary and secondary sources of data to obtain its information. The description of this two sources are elaborated in the below sections.

3.5.1 Primary sources of data

The study administered questionnaires to elicit information for ground truthing and for perception study. Both structured and unstructured questionnaires were used for farmers. For the selected households whose owners was absent, next household was chosen and interviewed, a total of 124 households were interviewed. To complement the household questionnaire data, 20 individuals from various organizations were interviewed key informants.

The study also used remote sensed data from land sat satellite images for the years 1984, 1990, 2000 and 2010. Due to unavailability of the past years NDVI images from
SPOT (i.e. 1980 upwards), those for the years: 2000, 2005, 2010 and 2012 were used. The study therefore validated GIS data with statistics method for precision.

3.5.2 Secondary sources of data

The study obtained data from published and unpublished works. For example, it obtained data from Kenya meteorological, Government of Kenya publications, books, articles, dissertations, theses and newspapers to supplement archival sources and accounts based on oral traditions.

3.5.3 Remote Sensing Data

For land use land cover changes, the study involved data acquisition, processing, analysis and interpretation activities. The years selected for the land use/land cover changes depended on the availability of the satellite images and were: 1984, 1990, 2000 and 2010. Choice of satellite imagery was based on spatial and radiometric resolution, availability of imagery in the years of study and affordability. LANDSAT satellite imagery was thus chosen as it is freely available, medium resolution, multispectral and good quality imagery in the years of study was available (Kenduiywo et al., 2013).

LANDSAT has 7 spectral bands. Bands 1, 2 and 3 are in the reflective visible segment of the electromagnetic spectrum, Band 4 in the reflective Near Infrared (NIR), Bands 5 and 7 in the reflective Short wave Infrared (SWIR) and Band 6 is in the emissive thermal Infrared (TIR) segment. The spatial resolution is 30 metres for all bands apart from Band 6 which has a spatial resolution of 120 metres (TM) and 60 metres (ETM) (Kenduiywo et al., 2013). LANDSAT TM imagery was used for 1984, 1990, 2000 and 2010. The spatial resolution of LANDSAT imagery and the fact that it is multispectral makes it a suitable source of data for environmental and climate studies since various band combinations provide information on the land surface and its properties.
3.5.3.1 Data Acquisition

Satellite imagery from Landsat TM (year 1984), TM (year 1990), ETM (year 2000) and ETM+ (year 2010) were obtained. The Landsat Thematic Mapper (TM) imagery provides seven multispectral channels (3 visible, 1 near-infrared, 2 mid-infrared, 1 thermal-infrared) at 30-meter resolution (120-meter resolution for the thermal-infrared band). Enhanced Thematic Mapper Plus (ETM+) adds an extra 15-meter resolution panchromatic band and improved resolution for the thermal-infrared band (60-meters). Landsat satellite images were acquired covering the area of interest that is the WPC.

The acquisition date of all the images is as shown in table 3.1 below

<table>
<thead>
<tr>
<th>Year</th>
<th>Image</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>P169R59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P170R58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P170R59</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>P169R59</td>
<td>1st March</td>
</tr>
<tr>
<td></td>
<td>P170R58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P170R59</td>
<td>27th March</td>
</tr>
<tr>
<td>2000</td>
<td>P169R59</td>
<td>27th January</td>
</tr>
<tr>
<td></td>
<td>P170R58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P170R59</td>
<td>6th March</td>
</tr>
<tr>
<td>2010</td>
<td>P169R59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P170R58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P170R59</td>
<td></td>
</tr>
</tbody>
</table>

3.5.3.2 Image Processing

Band combinations for the four sets of geo-referenced Landsat data were done to obtain color composites to enable interpretation. Bands 4, 3, 2 for TM and ETM+ images represent Red, Green and Blue (RGB). The bands help in vegetation enhancement, color contrast and also give more information. Erdas Imagine 10 was used to do the image processing and enhancement. Figures 3.2, 3.3, 3.4 and 3.5 below
shows the false color Landsat satellite images for years 1984, 1990, 2000 and 2010 respectively.

Figure 3.2: Landsat TM 1984 showing the false colours with the Visible (R, G, B) Image Prior to image classification for West Pokot County
Figure 3.3: Landsat TM 1990 showing the false colours with the Visible (R, G, B) Image Prior to image classification for West Pokot County
Figure 3.4: Landsat ETM+ 2000 showing the false colours with the Visible (R, G, B) Image Prior to image classification for West Pokot County
Figure 3.5: Landsat ETM+ 2010 showing the false colours with the Visible (R, G, B) Image Prior to image classification for West Pokot County

3.5.3.3 Image classification

The area of interest was clipped out from the images for interpretation. Visual interpretation was then done using MadCat software. This was done by segmenting the raster (vectorizing raster image into shape files for classification). Interpretation of these segments was done for all the years based on the interpreter’s skills and knowledge as well as using available ancillary data.
3.5.4 Vegetation Index- Normalized Differential Vegetation Index (NDVI)

Normalized Differential Vegetation Index (NDVI) images were used based on surface reflectance in the near infrared and the red bands and more data from the field visits and meteorological data were used in order to test the results and to provide interpretations for the NDVI images. SPOT 5 multispectral data sets were used in this study. SPOT-5 scenes have a 10m-pixel resolution and 4 spectral bands: band 1 (0.50-0.59μm: green), band 2 (0.61-0.68 μm: red), band 3 (0.79-0.89 μm: near infrared NIR) and band 4 (1.57 -1.75 μm: short-wave infrared SWIR) (Anim, 2013). The Normalized Difference Vegetation Index (NDVI) was extracted for each year of study and maps of NDVI were generated. Multispectral vegetation indices were represented by algebraic combination of remotely sensed spectral bands that indicated the phenology of the vegetation cover. For the state of the crops, the different sensitivity of the mentioned electromagnetic spectra was used to estimate the productivity of the study area.

3.6 Data analysis

Data analysis entailed image interpretation which included examination and detection of cropland in the area from the image. The NDVI anomalies for the years and changes in productivity observed between the subsequent years were also interpreted. The GIS Approach: Geographic information systems (GISs) provided a spatial framework to support spatio-temporal analysis of Landsat data. The GIS geoprocessing tools analyzed information based on vegetation indices and other spatial data. Softwares used included: Erdas Imagine 2011 especially for geometric correction, Arc Gis 10 for developing maps and MadCat for visual interpretation. For the questionnaires and interview schedules, SPSS was used for frequencies and cross tabulation for perceptions and excel used for analyzing temperature and rainfall data. Data obtained was displayed in form of maps, tables and graphs. Also photographs were used for ground truthing and visual interpretation.
CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Application of remote sensing and Geographic Information System technology on spatial variability in relation to climate variation in the county

This objective discussed the statistics on LULC in the study area that have been obtained from the step-by-step classification of land cover from Landsat satellite imagery of the specified years. Information and statistics obtained are used to provide information about the different land use practices in that area and using survey method, the study validated the findings i.e. whether the changes noted are due to climate variability. LULC analysis using statistics obtained is then discussed and analyzed. Land use data is collected in an effort to provide a basis of monitoring land use changes so as to detect change and its impact on the environment.

A total of five land cover classes were considered namely: Forestland, Cropland, Grassland, Settlements and Wetlands. Figures 4.1, 4.2, 4.3, and 4.4 below (for 1984, 1990, 2000 and 2010 respectively) show maps of the interpreted images of West Pokot County.
Figure 4.1: Land use 1984 indicating grassland as the dominating land use type
Figure 4.2: Land use 1990 indicating a decrease in grassland and forestland as cropland increases
Figure 4.3: Land use 2000 with an indication of a steady increase in cropland and settlement followed by a decrease in forestland and wetland.
Figure 4.4: Land use 2010 showing a steady increase in settlement followed by cropland as grassland decreases steadily
Table 4.1: Land use types in West Pokot County and the corresponding Area in Ha

<table>
<thead>
<tr>
<th>LANDUSE/ Area in Hectares (Ha)</th>
<th>1984</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>%change (1984-2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>79759</td>
<td>93586</td>
<td>101591</td>
<td>134253</td>
<td>68</td>
</tr>
<tr>
<td>Forestland</td>
<td>90725</td>
<td>85868</td>
<td>77302</td>
<td>77836</td>
<td>-14</td>
</tr>
<tr>
<td>Grassland</td>
<td>728309</td>
<td>721791</td>
<td>727189</td>
<td>687566</td>
<td>-6</td>
</tr>
<tr>
<td>Settlements</td>
<td>32</td>
<td>83</td>
<td>95</td>
<td>167</td>
<td>422</td>
</tr>
<tr>
<td>Wetlands</td>
<td>7774</td>
<td>5272</td>
<td>4226</td>
<td>6839</td>
<td>12</td>
</tr>
</tbody>
</table>

Land use types in West Pokot County and the corresponding Area in Hectares

Table 4.1 above illustrates the main land use types and respective hectares in West Pokot County for the years 1984, 1990, 2000 and 2010 respectively. Like many other regions in Sub Saharan Africa (SSA), study area continues to experience changes in LULC for the years 1984-2010. The results indicate a general decrease in areas under natural vegetation formations (forest and grassland) and an increase in areas under agricultural land.
Croplands dominated more in high and medium potential areas which included Kapenguria and Chepareria and has increased steadily (Ref. to figure 4.5 above). These results are in conformity with the results reported by Githui *et al.* (2009) in Nzoia Basin of Western Kenya who observed that the area under agricultural land increased from 39.6% in 1973 to 46.6% in 1986/1988 and to 64.3% in 2000/2001. Similar patterns of LULC change were also reported by Nambiro (2007). This increase in area under cultivation is in response to the increased demand for land to produce more food for the increasing human population. For example, the population of West Pokot County increased from 1979-158,652; 1989-225,449; 1999-308,086 to 512,690 in 2009 (Republic of Kenya, 2005; Republic of Kenya, 2010). Further, the smallholder agriculture that is predominant in the region is much less productive in terms of yield per unit of land. This has forced communities to seek extra land (extensification) as opposed to increasing production on existing areas (intensification).
Figure 4.6: Land use – forestland: Showing the trend of the forestland in West Pokot County over the years

The area under forest cover shows a decreasing trend followed by a slight increase in the year 2010 (figure 4.6). The patterns of forest destruction are reflected in the overall decline in the national forest cover from 10% in 1963 to 1.7% in 2006 (Masinde and Karanja, 2011). Between 1955 and 2004, the indigenous forest areas in the Taita Hills decreased by 50% (Maeda et al., 2010). Similar forest decimations have been reported for other areas such as Nandi and Kakamega (Mitchell and Schaab, 2006), Mt. Kenya and the Arberdares (NEMA, 2011). The decrease in west Pokot was attributed to clearing of forestland for crop farming and charcoal burning for income to substitute the decreased income from crop farming. Similarly, the changes in forest cover have mainly been attributed to forest excision to pave way for agricultural land expansion, charcoal burning, pit sawing, grazing and collection of fuel wood (Mitchell, 2004).
Figure 4.7: Land use – grassland: showing the trend of grassland in West Pokot County over the years

It is observed that the grassland dominates more in the low potential areas like Kacheliba though exhibiting a decreasing trend in terms of land coverage. In a study conducted by Chu et al., 2006, found out that there were several factors leading to grassland degradation, which included overgrazing, consuming biomass energy (mainly within the grassland) for domestic energy. The results conforms with those of West Pokot area (Ref. to figure 4.7 above), whereby the decreasing trend was in response to overgrazing, clearing shrubs within the grassland for charcoal burning, clearing of land for crop farming as well as land fragmentation due to permanent settlement as opposed to nomadism. The results corroborates with those of Kioko and Okello (2010) who noted that since the 1960s, the grazing range of the pastoral communities has continued to decline due to land fragmentation.
Wetlands shows a decreasing trend for the years 1984, 1990 and 2000 following the low rainfall and the resultant high temperatures experienced in the area over the specified years while in 2010 there is an increase due to the high rains experienced in the area (Ref. to figure 4.8 above). The results reflected that rainfall and temperature determines the wetland coverage hence water availability and therefore can be greatly affected by climate change and variations. The results agrees with those of DSE (2008) who also found out that climate change and variability are the biggest factors affecting water availability and reliability. 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 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 will likely increase tensions around scarce water and pasture resources.
Figure 4.9: Land use – settlements: showing the trend of settlements in West Pokot County over the years

Hitherto other land use types showing a decreasing trend, the area under settlement has been increasing steadily (Ref to figure 4.9 above). This follows the steadily increase in human population in the areas. For example, the population of West Pokot County increased from 1979- 158,652; 1989-225,449; 1999-308,086 to 512,690 in 2009 (Republic of Kenya, 2005; Republic of Kenya, 2010). The increase is in response to the nomads also permanently settling as opposed to the before temporary houses.

4.2 To characterize annual and seasonal rainfall and temperature from 1980 - 2011 in West Pokot county

4.2.0 Trend analysis of rainfall and temperature

The daily rainfall and temperature data for the period 1980-2011 from the Kenya meteorological department for West Pokot County was aggregated into monthly and yearly totals. The results were then analyzed for trend changes and presented in the figures shown Figure 4.2.1 below.
4.2.1 Rainfall analysis

Figure 4.10: Annual rainfall trend from 1980 to 2011 in West Pokot County

Figure 4.10 shows the annual rainfall variability of the study area. The main rainy season at local level between 1980 and 2011 revealed that the study area received variable rain. It is therefore apparent from the findings that there is no consistent rainfall trend observed overtime in West Pokot suggesting that the yearly rainfall trends were likely to be unpredictable. The results corroborates with Amissah-Arthur et al. (2002) observations when they characterized effects of El Nino events on rainfall trends in Kenya. Similarly, the pattern in WPC illustrates unpredictable cycle as heavy rains were often followed by scarce rains. Evidence of climate variability has become more pronounced in through the alternating cycles of droughts and floods (Huho and Kosonei, 2014). Examples mentioned by Kenya Red Cross Society, (2012) are the unpredictable cycles especially 2004 and 2009 experienced in Kenya where droughts...
were interposed with floods and caused devastating impacts on crop yields. Other studies by e.g. by Musingi (2013) noted that the 2008/9 drought episode was one of the severest on record in Kenya over the past decade with widespread socio-economic impacts, which included famine and a decline in the length of the growing season. West Pokot was not an exception, as observed the pattern as from 2005 (a sharp increase from the low rains of 2004) to 2008 (after which in 2009 rains declined) the rains were high. On the same, respondents affirmed that rainfalls have become irregular and unpredictable, and they said that when it rains, downpour is more intense resulting in destruction of crops especially if it is during maturity period of maize and beans. The findings are also in line with Haile’s (2007) findings that rainfall variability has a significant negative effect on the probability of growing crops including maize. As well the results corroborates with the global climate models which predicts 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) which will bring considerable reduction in the length of the growing season in the arid and semi-arid environments (Galvin et al., 2001).

The mean rainfall in WPC from 1980 to 2011 was 973.4 mm p.a. Years 1984 and 2000 experienced the lowest precipitation of 631.6 mm and 619 mm respectively. One farmer noted “the year 2000 was a year I can’t forget, I slept hungry most of the days due to crop failure, there was no rainfall for my crops to grow”. Similarly, during the year 2000, West Pokot was noted to have experienced very poor rains leading to serious food shortages and lack of water for both livestock and the human population. An assessment conducted by ACT Nairobi Forum led by Norwegian Church Aid (NCA) revealed near total crop failure with mixed farming zones realizing less than 10% food harvest. This resulted in a substantial rise in malnutrition levels especially among children and women. The intervention proposed in this regard was included distribution of relief food (see http://reliefweb.int/report/kenya/fews-kenya-food-security-update-august-2000). These results above can be harmonized by Ngigi (2009) who noted that most areas characterized by low and erratic rainfall, concentrated in
one or two rainy seasons may result in high risk of droughts, intra- and off-seasonal dry spells, and frequent food insecurity.

The highest amount of annual precipitation was received in 1982 totaling 1348mm p.a. followed by 2011 totaling 1308mm p.a. The year 1982 was also significantly noted by Dietz and Annemieke (1983) to have good rainfall with sufficient maize production. The authors in their study in WPC for the year 1982 noted that for most of the households in (at least three fourth) the maize production was sufficient. They found out that about half of the households gave away some food to far relatives, almost 3 tins of 15kg by each on average. Equally, GOK (2011), on its’ 2011/12 short rains season assessment report classified West Pokot as having none or minimal score on the acute food security phase classification. This meant the number of meals and dietary diversity was normal in West Pokot due to good harvest supported by enough rains. Comparing with 1980 and 1981 which had minimal rains Dietz and Annemieke (1983) found out that all households got famine relief.

4.2.2 Temperature analysis

Minimum and Maximum monthly daily temperature for WPC was obtained and average daily temperature per month and per year calculated for High lands of WPC (covers high food potential area and parts of medium food potential area i.e. Kapenguria and parts of Chepareria) and Low lands of WPC (covers low food potential area and parts of medium food potential area i.e. Kacheliba and parts of Chepareria).
Results from figure 4.11 above showed that from 1980 to 2012, in WPC lowland areas, the lowest annual daily temperature was in 1985 with 29.13°C, and the highest annual daily temperature was in 2009 with 30.38°C. The temperature range from 1980 to 2012 was therefore 1.25°C and average annual temperature was 29.74°C. The temperature range of 1.25°C in WPC lowland areas demonstrated that a significant rise in the temperature occurred between 1985 and 2012, and this corroborate the recent trends of global warming as reported by the Intergovernmental Panel on Climate Change (IPCC, 2012) report.
In West Pokot County highland areas (Figure 4.12 above), the minimum annual daily temperature was 18.39°C in 1985, and the maximum annual daily temperature was 19.68°C in 2005. Maximum and minimum temperature range from 1980 to 2012 was therefore 1.29°C and average annual daily temperature was 19.08°C. The temperature range of 1.29°C in West Pokot County highland areas showed that effects of warming temperatures are already being felt in the region even in the highlands. The results are consistent with previous studies in the region by King’uyu et al. (2000), Anyah and Semazzi (2006) on temperature variability trend anomalies in the highlands.

4.3 The phenology of agricultural vegetation in the West Pokot County

This section presents results for inter annual variation in NDVI assessment for WPC for the period 2000 to 2012. Figures 4.13, 4.14, 4.15, 4.16 below show the vegetation production represented by the NDVI images for years 2000, 2005, 2010 and 2012 respectively.
Figure 4.13: NDVI image for 2000 showing poor vegetation
Figure 4.14: NDVI image for 2005 with a slight improvement of vegetation greenness as compared to the year 2000
Figure 4.15: NDVI image for 2010 with the best vegetation greenness over the years studied
Figure 4.16: NDVI image for 2012 with a decrease in vegetation greenness as compared to the year 2010 above
Overall, vegetation greenness differed significantly with each other, with Kapenguria having highest greenness followed by Chepareria and Kacheliba with the lowest. The variability of these patterns show the underlying patterns of rainfall, vegetation formation and types which tend to vary in structure across the study area. However, despite the perceived decrease in vegetation attributes (Okoti et al., 2004), all the sites showed positive trends in NDVI through the satellite time series data. Results showed that there has been a consistent increase in vegetation greenness in the three study sites with the greenness increasing consistently from the lowest in 2000 to a peak in 2011 and decreasing in 2012 due to the respective decrease in rainfall recorded. In a similar study conducted by Omondi (2014) in Turkana area, he noted that the peaks and lows of the vegetation greenness naturally represent the rainy and dry periods. For example, the image for the year 2000 represents poor vegetation in both study sites with Kacheliba recording the very poor followed by Chepareria and thirdly Kapenguria. This was the year (under those considered) that recorded lowest rainfall in WPC with 619 mm. 2005 recorded better results with the green colour increasing its’ percentage especially in Kapenguria, Chepareria and Kacheliba respectively; the year had improved rainfall of 933mm. The year 2010 also showed healthy vegetation in both high potential zones following the noted increased rainfall of 1210mm. The NDVI pattern and the resulting NDVI maps therefore show NDVI is directly correlated with precipitation. A similar trend of ‘greening’ of drylands has been documented by (Vlek et al., 2010; Fensholt et al., 2012). Some authors stated that the greening observed in the arid lands is due to a gradual improvement in precipitation (Hulme et al., 2001; Vlek et al., 2008).

However the greening effect observed in the drylands could also be attributed to the Government’s and other development partners’ initiative to promote soil and water conservation practices (Omondi, 2014). For example extensive on farm tree planting programs have in the past been initiated by the Vi Agroforestry Programme and the World Agroforestry Centre.
The below graphical representations (Figure 4.17) demonstrates more on the relationship between NDVI and rainfall.

![Graph](image)

**Figure 4.17: NDVI values and Rainfall data for 2000-2010 in West Pokot County**

From the results, frequency of rainfall conditions over the decade is well represented by the NDVI anomaly patterns across the area during this study period. In general, the time series trends in NDVI indicate changes in NDVI over the specified years. The persistent nature of the seasonal effect on NDVI between 2000 and 2010 is in agreement with the historical patterns of rainfall anomalies observed in other parts of Kenya by Shisanya et al. (2011).

As noted in figure 4.17 above, the year 2000 had the lowest NDVI values due to the lowest rainfall amount in the area over the years; meaning that there was inadequate soil moisture and crop stress caused by little precipitation due to the resultant drought and very low rainfall. This shows that the vegetation growth in rain-fed agriculture is limited by rainfall availability and its’ unpredictability can have a significant effect on vegetation growth.
On the other hand, 2010 recorded higher NDVI values, meaning the vegetation was healthy and received enough rain. Moreover, it received the highest amount of rainfall for the specified years of the study. The relative density of vegetation in a year as determined by greater NDVI values for rain-fed agriculture is therefore a good indicator of crop yield in that year and also a good indicator of adequate amount of rainfall received. However, some studies e.g. Omondi, (2014) had argued that beyond rainfall, patterns of vegetation could also be influenced by inherent soil fertility status as well as the land use and land cover changes taking place either due to natural or human activities. Studies by Okoti et al. (2004) also established that in addition to rainfall amount, factors such as soil type, deforestation, overgrazing, and land use activities determine primary biological productivity. In the case of WPC, rainfall distribution, alongside bio-physical characteristics such as presence of high populations of human in Kapenguria and Chepareria and livestock in Kacheliba respectively could be a major determinant of vegetation greenness anomalies.

**Analysis of NDVI anomalies**

A number of studies conducted in arid and semi-arid ecosystems show that time series of remotely sensed NDVI can be a reliable indicator of physical climate variables including rainfall, temperature, and evapotranspiration in a wide range of environmental conditions (Nicholson et al., 1990, Anyamba and Tucker, 2001). The following graphs (Figure 4.18 below) show the deviation from normal NDVI data during 2000-2010 in WPC. Overall, the NDVI time series results show on average very low values from January to February and then afterwards increases and reaches a peak in June before it starts decreasing up to July. This pattern clearly shows close correspondence of monthly rainfall anomalies with NDVI. It can be thus summarized that NDVI anomalies, which are a culmination of how environmental factors (rainfall, soil moisture and temperature) act upon the land surface, have stronger linkages with monthly rainfall anomalies than any other climatic variable (Omondi, 2014). Results from the study conducted by Omondi (2014) confirmed that good correlation occurred
between average rainfall and NDVI for monthly data with a trend of increasing NDVI with rainfall. Overall, better correlation between rainfall and NDVI was observed in Kapenguria, Chepareria and Kacheliba.

The study findings revealed that driest years had the lowest NDVI values while the wettest years had maximum NDVI values. The analysis of the NDVI anomalies revealed that a drought in the county occurred in 2000 recording a negative NDVI anomaly i.e. NDVI for year 2000 was less than Mean NDVI (Average year smoothed). Similarly, a study conducted by Omondi (2014) mentioned that the OND rainfall in 1998, 2000, 2003, 2009 and 2010 recorded below normal rainfall for Lokichoggio, Kakuma and Oropoi in Turkana. Of the five years with below normal rainfall, the same author noted that 2000 had the most pronounced depressed rainfall with all the three sites recording a negative normalized precipitation index during the OND rainfall. Similarly, the current study in West Pokot result revealed that that 2010/2011 was not the worst hydrological drought year as reported elsewhere. For example, the lowest normalized rainfall values recorded for all the three locations by Omondi (2014) was -0.21 for MAM and -0.32 for OND rains in 2000, while the normalized OND rainfall in 2011 were all positive. This result was corroborated from the field response of the respondents showing 2000 drought as the worst in the county in recent years and crops were devastated. The results in West Pokot which showed that years 2005, 2010 and 2012 had both positive NDVI anomalies, with 2010 having a higher NDVI anomaly followed by 2012 then 2005 also tallied with rainfall data as well whereby 2010 was noted to have received a rainfall amount of 1210mm, followed by 2005 with 933mm. This results corroborates with other studies who have found that a strong correlation exists between vegetation production indexed by NDVI and average climatic distribution of precipitation in most ecosystems (Goward et al., 2003; Hellden and Tottrup, 2009), making it useful for understanding the effects of wet season months on vegetation greenness leading into the dry season.
Overall, the study findings largely show that there are rainfall variations in the study area as indicated by the NDVI value changes. Elsewhere, studies show that the large variations and trends in precipitation have resultant effects on vegetation dynamics, and ecosystem structure and functions, especially in the arid and semi-arid ecosystems where moisture availability is one of the most important constraints on vegetation growth and development (Anyamba and Tucker, 2005). Other similar studies also show that the mechanisms that govern atmosphere-plant-soil processes are strongly influenced by water availability and any subtle shift in rainfall influence the ability of plants vegetation to respond to such changes (Mortimore, 2009; Huber et al., 2011; Gaughan et al., 2012; Gessner et al., 2013).
Source: Author
Figure 4.18: Monthly NDVI values trend for years 2000, 2005, 2010 and 2015
The general crop phenology and characteristic growth in a year was summarised in figure 4.19 below.

**Figure 4.19: Mean NDVI values trend**

The rainy seasons makes a considerable contribution to crop growth, so averaging NDVI data for these months fairly represent the growing season for the region. The NDVI time series in West Pokot County results show on average very low values from January to February and then afterwards increases and reaches a peak in May before it starts decreasing up to September. This pattern shows close correspondence of monthly rainfall anomalies with NDVI observed over a short period of time. It can be thus summarized that NDVI anomalies, which are a culmination of how environmental factors (soil moisture and temperature) act upon the land surface, have stronger linkages with monthly rainfall anomalies than any other climatic variable (Omondi, 2014).
Table 4.2: NDVI vs. Mean Rainfall: Analysis of variance for mean rainfall and mean NDVI values

<table>
<thead>
<tr>
<th>Model</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of squares</td>
</tr>
<tr>
<td>Regression</td>
<td>.004</td>
</tr>
<tr>
<td>Residual</td>
<td>.023</td>
</tr>
<tr>
<td>Total</td>
<td>.027</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), meanRain
b. Dependent Variable: meanNDVI

However, in the analysis of relationship of rainfall and NDVI value when p<0.05 is significant, results showed that changes in NDVI value versus rainfall is not significant P=0.219 (Table 4.2 above) as supported by the lag in one month for NDVI to reach its’ peak. Results from the study in West Pokot County also show that although April and August are the peak rainfall months in the study locations, May and September are the peak NDVI months. Thus, after rainfall onset, there is a one month lag period for NDVI to reach its peak. In other studies, Malo and Nicholson (1990) suggested that the lag appear to relate to the fact that the vegetation does not respond directly to rainfall, but rather to soil moisture, which is a multi-months integral of rainfall. Previous studies by Anyamba et al. (2005) reported 1-3 months lagged response of rainfall and NDVI in eastern Africa after the 1997/1998 El Niño event. Similarly, Wang and You (2004) found that vegetation response to North Atlantic Oscillation delayed by 1.5 years. In other regions in Africa, Martiny et al. (2006) observed that the lag between the rainfall and NDVI peaks was smallest in western Africa with one month, and the highest in southern Africa with over 1.5
month, which was found to be related to the increased rainfall rate before the peak. The delayed effect of rainfall on vegetation anomalies has implications on the overall food web in the rangeland ecosystems (Holmgren et al., 2001). Funk and Brown (2006) have also used the lagged association between rainfall and NDVI to estimate vegetation response to current climatic conditions, helping to make early warning systems earlier for semi-arid communities in Africa. The close coupling between seasonal rainfall and NDVI values in West Pokot County can therefore enhance predictability providing a window of opportunity in planning for crop farming and water resources in the arid and semi-arid areas.

4.4 Perception of the household on the relationship between food insecurity and climate change in the area

4.4.1: Respondents views on climate variability occurrence from 1980-2012

Respondents from both study sites concurred that in the 1980s rainfalls and temperatures were more regular and predictable in seasons. Rainfall seasons for example were distinct, but currently, rains have become more unpredictable. Temperatures were also noted of increased. Temperature increases are known to have a significant impact on water availability, thus likely to exacerbate vulnerability of the farmers (Hererro et al., 2010). The Global climate models for the region indicate that by the year 2100, climate change will increase temperatures by about 4°C (Kabubo-Mariara, 2008). Moreover, 68 % of the respondents strongly believe that climate variability has occurred in the area and only 2% of the respondents reported of not experiencing climate variability. The study is comparable to elsewhere in Africa, for example in Ethiopia, farmers reported similar sentiments of reduced rainfalls and changed rainfall patterns (Mengistu, et al., 2011). Comparably, in the neighboring Southern Ethiopia, Deressa et al. (2011) observed a complex rainfall and temperature trend patterns, with average minimum and maximum temperature increase of about 0.25 and 0.1, respectively, over the past decade, whereas rainfall patterns was
characterized by unpredictable trends for the past 50 years. Farmers in Southern Africa region also termed perceptions of droughts, floods, reduced rainfalls as stressors (Mubaya, 2012). Thus as farmers give value of climate perceptions, the study interpreted their valuing as emphasis of what variability entirely means to these farmers’ agriculture and their livelihoods in general.

According to the interviewees, the long rains occur between March and May, while the short rains occur between August and November. Farmers explained that rainfalls have reduced in both quantity (amounts per rainfall) and quality in comparison to the time they settled in the area. Changes in rainfall amount and patterns, affects soil erosion rates and soil moisture, both of which are significant for crop yields (Kotir, 2011). In addition, varying temperatures make it difficult for the crops to grow with little rains. These findings show the ability of farmers to value their climate as either ‘good’, ‘bad’ or ‘very bad’, which farmers are able to define subjectively is an indicator of their in depth local knowledge and perceptions.

4.4.2: Effect of climate variability on crop production

The reduction of crop production was attributed to either low rainfall or erratic rainfall patterns coupled with extreme temperature conditions. These observations by respondents correspond with reports from weather stations that revealed high level of variability of rainfall distribution over the past three decades in the arid and semi-arid environments of Kenya (Shisanya et al., 2011). Also, the results corroborates with Moron et al. (2013) who noted that Kenya’s intra-seasonal component is intrinsically unpredictable. Farmers concurred that they had experienced severe droughts in several years, quoting year 1984 and 2000 as years with most severe droughts that culminated in losses of livestock and crops. Loss of crops and decrease in crop yields was translated as food shortage by the respondents, hence their perception of increased hunger. In literature, droughts are identified as a potential risk and source of losses in agricultural production (Herrero et al., 2010 and Ericksen et al., 2011). An increase in
the frequency of droughts in a region leads to decreased agricultural production (Mude et al., 2007).

The results on the extent of climate variability impacts on crop production as summarized in Figure 4.20 below show that in Kapenguria, 14% respondents believe they have been greatly affected, 84% respondents believe they have been slightly affected and 2% respondents believe they have not been affected. The decrease was mostly attributed to varied rains and increased temperatures. According to IPCC (2007) increased temperatures is also expected to reduce crop yields and increase levels of food insecurity even in the moist tropics with predictions that during the next decade millions of people particularly in developing countries will face major changes in rainfall patterns and temperature variability regimes. This is expected to increase risks in the agricultural sector (Gornall et al., 2010). In Chepareria, 27% respondents believe they have been greatly affected, 66% respondents believe they have been slightly affected and 7% respondents believe they have not been affected. In Kacheliba, 75% respondents believe they have been greatly affected, 25% respondents believe they have been slightly affected and none of respondents believe they have not been affected. In general, 34% respondents believe they have been greatly affected whereby Kacheliba was the most affected due to its’ increasing aridity and highly variable and unpredictable rains. Sixty three percent of the respondents believe they have been slightly affected and 3% respondents believe they have not been affected.

In a similar study conducted by Kalungu and Harris (2013) on smallholder farmers’ perception on changes on crop productivity in the semi-arid and sub-humid Regions of Kenya in reference to climate variability results showed that 80% of farmers from all sites perceived more changes in crop productivity for the past 30 years following differences in climatical conditions. For instance, the study indicated that 74.4% of farmers in semi-arid region perceived changes in crop productivity while 57.85% of farmers from sub-humid region perceived changes in productivity for the past 10 years. Therefore climate variation is reported to have led to decrease in crop
production and that there is need for a decisive policy if the area is to be preserved to produce adequate food in the future.

4.4.3: Change in crop growing seasons

The respondents were asked if they had experienced any changes in crop growing seasons. Their response is as shown in the figure 4.21 below.

Length of growing season variations is a useful climatic indicator and has several important climatological applications (Robeson, 2002). Changes in rainfall patterns, in
addition to shifts in thermal regimes, influence local seasonal and annual water balances and in turn affect the distribution of periods during which temperature and moisture conditions permit agricultural crop production (Herrero et al., 2010). Such characteristics are well reflected by the LGP since Kenya mostly relies on rainfed agriculture (Fischer et al., 2002; Comprehensive Assessment, 2007).

From figure 4.21 above, in Kapenguria, 33% respondents said that crop growing season was shorter than before; 55% respondents said was same as before, while 12% respondents said it is longer than before. In Chepareria, 46% respondents said it was shorter than before, 39% respondents said was the same as before, while 15% respondents said it is longer than before. In Kacheliba, 57% respondents said it is shorter than before, 9% respondents said is the same as before, 6% respondents said it is longer than before, 3% respondents said is much longer than before, while 25% respondents said it varies year to year depending on rainfall. The growing seasons were therefore highly variable depending on the AEZ which as well coincides with FAO (2011) report which also found out that the lengths of growing periods in the three agro-ecological zones of WPC vary from 150 days in the highland site to 110-120 days in the lowland and mid-hill zones.

However, majority (44%) respondents said it is shorter than before due to higher temperature and precipitation deficit hence crop dries faster albeit with small grains due to less rains. A decrease in length of growing season could result, for example, in alteration of planting dates determining lower yields of traditionally planting crops, which may not fully mature (Linderholm, 2006). Bearing in mind that in many areas with alternating wet and dry seasons, the annual rainfall is less than the amount of the water that a crop well supplied with water would transpire during the growing season (Ayanlade, et al., 2010) hence affect the entire crop growing cycle. Thirty eight percent of the respondents said the length of growing season was the same as before, 11% respondents said it was longer than before, 1% respondents said is much longer than before, while 6% respondents said it varies year to year depending on rainfall.
This meant that the group is highly vulnerable based on weather fluctuations and climate variability playing a significant role in crop growth and yield. Literature notes that occurrence of abnormal weather episodes during any growing season or during critical development stages may hamper growth processes resulting in yield reduction. This makes climate variability a threat to food production leading to serious social and economic implications (Geng and Cady, 1991; Hossain, 1997).

4.4.4: Views on changes in crop yield over the years

Farmers constantly stressed on declining crop production due to unpredictable, sometimes incessant rains, as well as low rainfall, coupled with high temperatures on the other hand, and the occurrence of extreme climatic events including hailstorms and frost especially in Kapenguria. Their results concurs with those of IPCC (2007) which predicted that by 2050, crop yields in Sub-Saharan Africa will have declined by 14% (rice), 22% (wheat) and 5% (maize) pushing the vast number of already poor, who depends on agriculture for their livelihoods, deeper into poverty and vulnerability. Parry *et al.* (2004) had also found that climate change is likely to lead to declining crop yields and to increase the disparities in cereal yields between developed and developing countries.

Figure 4.22 shows that in Kapenguria, 49% respondents said crop yields has declined, 24% respondents said crop yields was stable, while 27% respondents reported that crop yields had increased. In Chepareria, 61% respondents reported that crop yields had declined, 27% respondents reported crop yields was stable, while 12% respondents said crop yields had increased. In Kacheliba, 97% respondents reported that crop yields had declined. None of the respondents reported crop yields was stable, while 3% respondents reported crop yields had increased. In general, 65% of respondents reported that crop yields had declined. The results also support earlier studies that have found that climate change is likely to have adverse effects on farm productivity in Africa (Massetti & Mendelsohn, 2011; Kabara and Kabubo -Mariara,
The result also concurs with those of Braun (2007); Pingali (2012) who noted that the ongoing climate change is forecasted to reduce crop yields in many parts of the world.

However, those from the lowland were impacted most due to increasing aridity in the area following the increasing temperatures with unpredictable rains coupled with frequent droughts. This defines their vulnerability to food insecurity and validates IPCC (2007) conclusions that the eastern and northern arid and semi-arid lands (ASAL) are expected to see an overall decrease in precipitation due to climate change and variability. Sixteen 16% of the respondents said crop yields had increased could be attributed to those who practiced irrigation as an adaptation measure and the higher population density in especially the highlands (who reported of 27% increase) than the lowlands who reported 3% increase. Literature suggests that population density is a proxy for agricultural adaptation options (Kurukulasuriya and Mendelsohn, 2008). Population density could also capture availability of farm labor. The positive significant effect on maize and beans could be interpreted as suggesting that adaptation to climate change and availability of family labor are associated with increased yields and thus food security (Mariara and Kabara, 2014).

![Figure 4.22: changes in crop yield over the years in the study area](image)
4.4.5: Weather forecast information access by the respondents

Availability of climate information is a prerequisite for climate-informed decision making (Dinku et al., 2014) to strengthen the resilience of the poor and the vulnerable against climate variability and change (Fischer et al., 2002). The respondents were asked to explain whether they have access to weather forecast information for early warning purposes and from which source (Table 4.3). Sixteen percent of the respondents from Kapenguria, 10% from Chepareria, and 22% Kacheliba did not have access to any form of weather forecast information. In total, 15% of the respondents did not have access to any weather forecast information. Drawing from the respondents’ perceptions, it is clear that the study area is and will be more vulnerable to dry spells, droughts and to some extent, violent storms. This group practiced farming with no knowledge of weather changes at all. The concern is that they may not be adequately empowered to respond and adapt to the projected magnitude of climate changes (Boko et al., 2007). Other studies have made similar observations. For example, a study conducted by Gwimbi (2009) in Gokwe District of Zimbabwe, reveal that more than 70 percent of the surveyed farmers lacked access to timely weather forecasts. Further, related studies (for example, Ziervogel et al., 2004; Lemos and Dilling, 2007) highlight that forecasts have not been extensively embraced and their effective utilisation has lagged behind, particularly among marginal. Climate information and support services play a critical role in providing Early Warning Systems (EAS) as well as increasing awareness for building the capacity and disaster preparedness to a changing climate.

However, 54% of the respondents obtained their source of weather forecast information primarily from radio and 15% from traditional forecasters. Cherotich, et al. (2012) noted that the choice of the dissemination channels can influence access and use of climate information and service disseminated to enable the vulnerable groups exposed to climatic hazards build adequate response capacities. Hansen et al. (2007) argues that radio and ICT based communication offer immense potential to support the
delivery of climate information support services; but cannot replace the trust, visual communication of location-specific information, feedback and mutual learning that face-to-face interaction provides. Their responses are summarized in the table 4.3 below

Table 4.3: Access to weather forecast information in the study sites

<table>
<thead>
<tr>
<th>Agro-ecological zone</th>
<th>% Source of weather forecast information</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kapenguria</td>
<td>Chepareria</td>
<td>Kacheliba</td>
<td>All</td>
</tr>
<tr>
<td>Traditional forecasters</td>
<td>2</td>
<td>22</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>Radio</td>
<td>60</td>
<td>54</td>
<td>44</td>
<td>54</td>
</tr>
<tr>
<td>Radio &amp; Traditional forecasters</td>
<td>14</td>
<td>12</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Radio &amp; Government extension agents</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Local elders</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Radio &amp; TV</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>TV</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Do not access</td>
<td>16</td>
<td>10</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Total %</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Farmers accessed forecast and early warning information through the radio, traditional forecasters, TV, government agents, and local elders. The choice of the source of information was so narrow unlike other studies conducted in Bangladesh, Ghana and Uganda by Chaudhury et al. (2012) which found a diverse of information sources which included: radios, newspapers, mobile phones, public announcements at schools and during religious gatherings, and print media as important channels for receiving weather forecast information.

The weather forecasting and early warning information should not only be available, but more importantly it should be understandable, reliable, credible, trusted, relevant,
useful, appropriate and context specific to the users for it to have a positive impact (World Bank, 2012; Mase and Prokopy, 2014; Winsemius et al., 2014). Fewer respondents indicated that the information they received was reliable, rather the majority of respondents indicated that the information was only ‘reliable at times’.

A high percentage (54%) obtained the information from the radio seconded by traditional forecasters. The respondents reported that radios were easily available to listen to and weather forecasters were even termed effective and trusted than the radios. Radios were mentioned to be only reliable at times and rarely do them. It is vital to point out that the reliability of forecasts is dependent on both the skill of the forecast and the credibility of the source (Ziervogel et al., 2004). Thus, improving the generation and presentation of forecasting information and addressing the barriers to its usage should be coupled by investing in the decision-making context (Coughlan and Mason, 2014).
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Overall, the observed monthly, seasonal and annual rainfall variability implies that rainfalls are highly unpredictable and varies across the agroecological zones, and therefore, the region exhibit non-equilibrium dynamics as described by Ellis and Galvin (1994) in similar ecosystems. The unpredictable rainfall and temperature trends in temporal domain, provides the incentives for debating on the rainfall variability in the arid environment and by extension on climate change. This kind of scientific information is essential for timely adjustment to extreme climatic events, especially intermittent droughts that often plague the arid and semi-arid regions.

This study has shown the area is warming at 0.25°C, in the lowland and 1.29°C in the highlands for the period 1980-2012. The increases in temperature are in line with community perception on climate change in terms of warmer days, extreme droughts and increase in temperature. Majority (68%) of the household respondents, who perceived climate change, indicated that it leads to low crop yield, food insecurity and decline in crop-productivity. Information on how communities perceive climate change could lead to a better understanding of possible interventions that suit farmers’ needs and support them to adapt with climate variability and change.

This study has assessed how rainfall and temperature variability have affected the food situation in West Pokot, tracing the long term data from 1980 to 2012. It has detailed their perceptions and narrated their past history on local climatic conditions. Empirical results show that 68% of the respondents feel that the local climate has greatly changed as compared to before. They termed it as being “bad” at the moment. They talked of frequent dry spells mostly caused by seasonal shifting of the short and long rains and increased variability of temperatures especially in the low potential zones. The years they mentioned of being the worst i.e. 2000 and 1984 matched with the past climate data from the meteorological department which showed low rainfall
experienced in the specified years. Importantly, the degree of impact of climate variation was higher at the low potential zones followed by medium potential and finally higher potential zones.

The study has also investigated the agricultural changes that have occurred in West Pokot during the 40 year era. The study shows that the change in climate has significant effect on agricultural productivity. This is clearly revealed in the rainfall variable, however temperature seem not an important variable of climate in determinants of agricultural productivity in WPC. In addition, this study has provided considerable evidence to show that for the past 10 years, stable food security in West Pokot has been difficult to achieve due to the highly variable rainfall variations. Households have had to fully utilize all potential resources of the area in seeking food security. For example pure pastoralists have moved to crop farming. For spatial variability evaluation it was noted that climate variability had effects on increasing cropland and decreasing wetlands, grassland and forestland. The increased cropland and decreased grasslands were the most pronounced land-use changes from 1984 to 2010.

5.2 Recommendations

This study has demonstrated that West Pokot County’s vulnerability has been significantly affected by climate variability and change and attributed by the respondents’ perspectives. Therefore, integration of indigenous households’ perceptions of climate variability and change with scientific meteorological data on rainfall and temperature trends are necessary for better planning and targeting of interventions.

The study area has undergone significant LULC changes some of which may result in negative impacts on the capacity of the land to provide ecosystem goods and services. For example, the threat of agricultural/cropland expansion is immense. There is a need to promote intensification of production on existing land holdings to minimize the
increasing demand for virgin land. Promotion of off-farm income generation activities can also help reduce overreliance on land. NDVI indices from satellite data can be used effectively to monitor climatic conditions and relate with food security. NDVI has been proved to correlate with rainfall received available on a continuous basis and can be used in monitoring drought on near real time basis as well as in trend analysis. NDVI data can be applied in both quantitative and qualitative analysis of drought. The data can be used to assess drought duration, intensity and spatial distribution of drought conditions hence be useful in drought management.

Nonetheless, it can be noted that the observed NDVI trends in West Pokot County cannot be exclusively be explained by rainfall anomalies, since there are a number of human factors that impact of vegetation dynamics including land use land cover changes. Thus, further research could focus on investigating climate variables and human-induced factors in vegetation variability, as well as long-term monitoring of the arid ecosystems.

5.2.1 Recommendations for further research

1. Influence of annual and seasonal rainfall on NDVI trends is explained in this study, however, it was concluded that the observed vegetation greenness anomalies in West Pokot County could not exclusively be explained by rainfall data. Thus, there is need to develop a robust approach that could distinguish between climate-induced vegetation variability and other anthropogenic factors in arid environments.

2. The increasing extension of cropland and the resultant reduction in grassland as coping strategy by the West Pokot community need to be understood better in terms of socio-economic and ecological sustainably especially with the challenges of future climate scenarios. Research may also need to investigate the trade-offs to better understand the effects on other ecosystem services in West Pokot.
REFERENCES


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APPENDICES

Apèndix 1: Field questionnaire

1. Please answer each of the following questions as honestly as you can.
2. Your answers will be treated confidential

PART A

Questionnaire No. …………………… Date …………………

GENERAL INFORMATION

1. Household member (name) (……………………………….)
2. Address (…………………………)
3. Location (………………………) Village (…………………………)
4. Ecozone  Masop [  ] Kamas [  ] Temko [ ] Lalwa [ ]
5. Age in years: (……………….)
6. Sex:          Male (  )        Female (  )
7. Did you attend school?       Yes  (  )       No  (  )
8. What is the size of your household (……………persons)
9. What is your source of your income? [  ] Farmer[  ] Salaried employment [ ] Business[ ] Others
10. What is the approximate size of your farm? (……………….Acres)

PART B

1. State the number of years have you lived in this area? (………………..)Years/months
2. Does your household normally undertake crop farming?  Yes (  ) No ( )
3. If yes in (2) above, is it done by irrigation or rain fed? Irrigation [  ] Rain fed [ ]
4. What type of crops do you grow in your area?..................................................................
5. How has been your production overtime since last year up to now? Increased [ ] Decreased [  ] Remained the same [  ]
6. Do you have enough food for your household currently?       Yes ( ) No ( )
7. Are these foods enough to sustain you?  Yes ( ) No ( )
8. What do you think about next year? Will be enough [  ] Will not be enough [ ]
9. Has there been any project targeted at improving the food insecurity condition in your area? [  ] Yes [  ] No
10. How would you rate the quantity of food in your household?
    a.  [  ] Very good [ ] Good [  ] very bad [ ] Bad
11. How has climate change affected food production for your household since last year up to now? [  ] Greatly affected [  ] Slightly affected [  ] Did not affect
12. Do you take any measures to reduce your exposure to the impacts of climate change on food security risk?
    a.  Yes ( ) No ( )
13. If yes in no.12 above, which measures do you undertake?
14. [ ] Expansion of cultivated land for agro pastoralists  [ ] Pay attention to climate forecast/early
warning systems  [ ] Acquisition of drought tolerant to plants  [ ] Crop cultivation for
pure pastoralists  [ ] Migration  [ ] Supplementary feeding
[ ] Others (specify)
15. Have you ever accessed any forecast information for the past 12 years for any rainy season?
   Yes (  ) No (  )
16. If yes in (15) above, what source of information did you access and how much confidence do
you have in forecasts from the specified source?

<table>
<thead>
<tr>
<th>Source from which the respondent access</th>
<th>Level of confidence in the forecast</th>
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<tbody>
<tr>
<td>Radio</td>
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<tr>
<td>Newspapers</td>
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<tr>
<td>TV</td>
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<tr>
<td>Traditional forecasters</td>
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<td>Government extension agents</td>
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<td>Local elders/religious elders</td>
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<td>NGO extension agents</td>
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</table>

17. If forecasts about a coming rainy season could be provided reliably, what type of forecast
information will be most useful to you?
   [ ] Forecasts about when rains are expected to fall in your area
   [ ] Forecasts about when rains are expected to end in your area
   [ ] Forecasts about whether the amount of rainfall will be above average, normal or below
   average
   [ ] Forecasts about the distribution of the rainfall during the season

18. If forecasts about a coming rainy season could be provided reliably, what type of forecast
information will be most useful to you?

20. How do you feel the following climate related factors have changed in the past 12 years?

   a) The total amount of rainfall per year
      Increased a lot  Increased  Stayed in the same  Decreased  Decreased a lot

   b) Length of growing periods
      Much longer  Longer  Stayed in the same  Shorter  Much shorter

   c) Temperatures
      Much hotter  Hotter  Stayed in the same  Cooler  Much cooler

   d) Incidence of food insecurity
      Much more insecure  More in secure  Stayed in the same  Less insecure  Much less insecure

   e) Rainfall occurrence
      Much more variable  More variable  Stayed in the same  Less variable  Much less variable

PART C
1. How many crop growing seasons do you have in a year for each of the crop type named
below? Answer as 1, 2, 3 or more

<table>
<thead>
<tr>
<th>CROP TYPE</th>
<th>Seasons/Year</th>
<th>Specific months in a year</th>
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</thead>
<tbody>
<tr>
<td>Maize</td>
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<td>Beans</td>
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<td>Wheat</td>
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</tbody>
</table>
2. Are the above named crops growing seasons regular annually or they have changed over the years since last year? Regular [ ] Changed [ ]
3. Did your household grow any crops during the last twelve months by season? [ ]
4. Which specific years have you ever experienced shift or extended crop growing season? [ ]
5. Has the area of your land which was under crop production reduced since 2 years ago? Yes ( ) No ( )
6. If yes in no.41 above what do you think might have been the reason? [ ] Converted to livestock keeping [ ] Became marginalized [ ] Became unfertile due to climate change [ ] Others (specify) [ ]
7. How do you obtain enough food for your household when the size of land under crop production reduces? [ ] buy food [ ] Depend on livestock products [ ] Depend on relief food [ ] Others (specify) [ ]
8. How many hectares of land were under crop production in last year? (……………..) Acres
9. How many hectares of land were under crop production this year? (……………..) Acres
10. In your opinion, what do you think will be the size of your farm in next year? (……………..) Acres
11. How has the crop yield from your farm been changing overtime since ten years ago? Increased [ ] Declined [ ] Stable [ ]
12. What is your opinion about the land cover/land use changes in your area in regard to food security? [ ]

PART G
Perception questions/ Household Questionnaire

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<th>More</th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>1. Do you understand what is climate change</td>
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<td>2. How much do you understand about climate change</td>
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<td>3. Do you believe that climate change is taking place</td>
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<td>4. Do you believe that climate change has reduced crop production in your area</td>
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<td>5. Do you believe that all people should know something about climate change</td>
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<td>6. Do you believe that food security is changing from better to worse due to rainfall and temperature changes</td>
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<td>7. Do you participate in any activity to adapt to climate change on food security in your area</td>
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<td>8. Do you associate climate change and food shortage</td>
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<td>9. Do you believe that problems related to climate change and food security will be reduced if early warning measures were communicated in time</td>
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<td>10. Do you believe that Government Policy in Kenya covers issues of global warming?</td>
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<td>11. Do you believe that if climate change impacts are not solved now, the future generations will suffer</td>
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<td>12. Do you believe that a degraded and devegatated environment is not as a result of climate change</td>
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<tr>
<td>13.</td>
<td>Do you believe that climate change has not reduced crop production in your area</td>
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<td>14.</td>
<td>Do you believe that only the old people should know something about climate change</td>
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<td>15.</td>
<td>Do you believe that food security has improved in your area overtime</td>
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<td>16.</td>
<td>Do you belief in the early warning measures to be accurate</td>
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<td>17.</td>
<td>Do you belief that the early warnings are useful to you</td>
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<td>18.</td>
<td>Do you belief that land use/land cover changes is as a result of climate change</td>
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<tr>
<td>19.</td>
<td>Do you agree that the meteorological department always makes timely the early warnings</td>
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</table>
Appendix 2: Photos of selected areas in West Pokot County

A photo of Kapenguria area representing the high potential zones of West Pokot County

A photo of Chepareria area representing the mid potential zones of West Pokot County
A photo of Kacheliba area representing the Low potential zones of West Pokot County