CLIMATE CHANGE IMPACT ON AGRICULTURE: CHALLENGES ON MAIZE PRODUCTION IN UASIN GISHU AND TRANS-NZOIA COUNTIES

By

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DECLARATION

This dissertation is my original work and has not been presented for the award of any degree in this university or any other university.

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ABSTRACT

Climate variability and change remains the major source of variations in global food production and specificallyin third world countries. The countries situated in the tropical regions experience the highest climate variability. In Kenya maize is the staple food and hence food security in the country depends on its production. Whereas maize is grown across a large range of ecological zone, Uasin Gishu and Trans-Nzoia counties are the leading counties in maize production. Despite the maize crop being a staple food crop; it depends on climatic conditions for its production. Hence any climatic change affects its production either ways. This research work investigated the impact of variations on rainfall and temperature on production of maize. The study sought to investigate: the nature of the variability and changes in temperature and rainfall in Uasin Gishu and Trans-Nzoia counties; the relationship between production of maize and variations in climatic elements in Uasin Gishu and Trans-Nzoia counties; challenges maize farmers face due to climatic changes and the economic effects of change in climate on maize production in Uasin Gishu and Trans-Nzoia counties. The data analysed for the study included; the monthly rainfall, monthly maximum and minimum temperature and a survey. An explanatory survey design was adopted in this study. The target comprised all large scale maize farmers in Uasin Gishu County. Data was collected using questionnaire. Qualitative data was analyzed descriptively based on emerging themes. Correlations coefficients were computed to identify relationships between study variables. To establish the economic impact of climate change on maize production, the Ricardian Model was chosen for the study. The study showed that the rainfall during the March to May (long rains) season over both counties has decreasing trend which was however insignificant, while the October to December (short rains) and July and August rainfall (short rains)showed positive trend which were also insignificant. Both the maximum and minimum temperature over both counties showed increasing trend for all the months. Just like for the case of rainfall, increased variability is observed in the maximum and minimum temperatures and indicates an increase in frequency of extreme high and low temperature. Over counties, rainfall and temperature series exhibits quasi-periodic cycles with peaks centered around 3-4, 2.2 -2.8 and 8-11years. These cycles are related to El-Nino Southern Oscillation (ENSO) and Quasi-Biennial Oscillation (QBO) and the sunspots. The correlation between rainfall, temperature and yield was positive during some months and negative during others. However, the month of September in both counties were noted to have a high correlation of yield and rainfall of 0.653 and 0.624 for Trans-Nzoia and Uasin Gishu respectively which was significant. The correlation between maximum temperature and yield was relatively high in May (0.126) and July (0.100) in Trans-Nzoia while May (0.274) and July (0.187) in Uasin Gishu County. However these correlations were not significant. For minimum temperatures, the correlation with yield was relatively high between June (0.339), July (0.204) and August (0.198) at Trans-Nzoia which were also not significant.Correlation between minimum temperatures and yield was relatively high between July (0.569) and August (0.514) in UasinGishu which was significant.During the growing period the relationship between climatic elements and yield was observed to be non-linear. On gender, large scale farming is dorminated by males who accounted for 82.7% of the respondents. Those aged between 18-40 years represented 36.4% while those above 41 years and above accounted for 63.6%. There is need for more young people to be involved in large scale farming due to the aging of the sizeable number of large scale farmers. Maize farmers faced challenges which were as a result of variability in precipitation amounts and temperature ranges. These were:

effect on phenology (maize sowing, flowering and grain filling), poor yield, poor quality maize crop harvest, increased maize pests and diseases which had a subsequent bearing on cost of maize production, uncertainty in yield quality which subsequently affected the general farmers' planning calendar. However, majority of the respondents cited effect on phenology as a major challenge. It was established that climate change had an economic impact on maize production. The results indicate that the final net farm revenue is more sensitive to changes in temperature than changes in precipitation. There exists significant non-linear relationship between final net farm revenue per hectare and climate variables. The study underscores the need to educate maize farmers on climate change by giving such information; proper management of the few fresh water resources available; enhance a paradigm shift from rain fed to irrigation based maize production which may not only increase production but make maize resilient to climate change; and, inform maize farmers on climate change and its likely impacts on maize production. This requires that the government sets up effective extension service programs in all the counties in the country.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

CSC	Climate Sensitivity Concept
FAO	Food and Agriculture Organization
FAOSTA	Food and Agriculture Organization Statistics Databases
GDP	Gross Domestic Product
IAASTD	International Assessment of Agriculture Knowledge, Science & Technology Development
IISD	International Institute on Sustainable Development
IPCC	Inter-Governmental Panel on Climate Change
IMWIC	International Maize and Wheat Improvement Centre
MEMR	Ministry Of Environment and Mineral Resources
MOA	Ministry of Agriculture
NST	Near Surface Air Temperature
UNEP	United Nations Environment Programme
WFP	World Food Programme
IFAD	International Food Agriculture and Development
WMO	World MeteolorogicalOrganisation
UNDP	United Nation Development Programme

DFID	Department of Foreign Investment & Development**.**
USA	United States of America

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Problem of the Study

Maize production and food security in Kenya are intertwined. This is true given that maize is widely used in the country as staple food. Hence food security in Kenya relies on favourable climate as most of maize growing is rain fed. At the unit household level in particular the village levels; food security is determined by availability and affordability.

Whatever is in the granaries for most rural families may be in most cases be equated to food security. Apart from being source of food at household level, maize is also source of income for farmers. In Kenya it accounts for about 14% of household income (Nyoro, *et al.,2004*).Maize yields are in the decline despite the fact that the area under cultivation have increased. Maize growing in Kenya is rain-fed. Apart from other climatic, edaphic, human and economic factors, rainfall and temperatures are major determinants of maize yields. Climatic data indicates that, temperatures in Kenya are rising at the rate of 0.6 degree Celsius per decade, World Bank (2012). The increase is higher than global or Southern Africa rates. It is against this background that this study has analyzed temperature and rainfalls trends for the last 32 years since 1980 against maize production over the same period to establish the effects of climate change on production of maize.

Climate change is an environmental problem which is complex in nature not only in Kenya but globally. The issue is made complex due to human population growth which exert pressure on diminishing natural resources found in the land. Climate change has its own consequences including but not limited to increase in diseases and vectors, poor crop yields and soil erosion. Crops yields due to rain fed agriculture crops including maize in Kenya are set to decline by almost 50% by 2020 (Ojwang, *et al*., 2010). This raises serious questions about Kenya's ability to feed its population since agriculture in Kenya is rainfall dependent.

1.1.1 The Climatic Conditions and Agro-Ecological Zones of Kenya

Kenya has a complex climate with wide variations across the country. At the coastal region, there exists a narrow belt which is relatively hot and wet. Behind this, lies a large area of hot and dry arid and semi-arid region. Thereafter, the land rises to form the temperate highlands. Kenya's complex climate is influenced by such factors as topography, its nearness to large water masses like Indian Ocean and Lake Victoria and the equator (Ojwang, *et al*., 2010). Kenya has duo rainy seasons namely: the prolonged rain season that begins in March to May and the depressed rain season that begins in October to December (McSweeney, et al., 2008). The highest amount of rainfall in Kenya is received in the highlands and a narrow coastal belt along the Indian Ocean while the least amount is recorded in the North eastern region of the country and around the Lake Turkana. The mean annual temperatures for Kenya range from 10^0C to 40^0C. Temperature, like rainfall is also dependent on altitude. High altitude areas have the coolest temperatures while low lying coastal belt and arid and semi-arid areas have the highest temperatures (Kabubo-Mariara and Karanja, 2007).

The country can be zoned into seven agro-ecological zones on the basis of vegetation, rainfall and ecological potential. These zones are the sub-humid, humid, semi humid, semi humid to semi-arid, semi-arid, arid and very arid. The high to medium potential areas of the country comprise of humid, sub humid and semi humid zones and make up 20% of the Kenyan land area. The two counties under the area of study are found within the high potential area of the country. The largest part of the Kenyan population, about 80%, is located in these zones. In addition, most of the crop agriculture practiced in Kenya is undertaken in these zones. The remaining agro-regions total to 80% of the Kenya's land area. The main economic activity here is livestock keeping and tourism. Majority of national parks in Kenya and game reserves are located in these areas (Ojwang, *et al.,* 2010).

1.1.2 Climate Change in Kenya

Just like the rest of the world, climate in Kenya have gone under metamorphosis over the years. On average temperatures in Kenya have increased by 1^{o}C since 1960 which translates to about 0.21^{o}C per decade (McSweeney et al, 2008).Changes in annual rainfall have increased. The long rains season which is experienced between March and May has shown a declining trend. Conversely the short rains which fall between October and December has shown an increasing trend. Equally extreme weather conditions like flooding and frequent droughts are showing increased trends.

1.2 Statement of the Problem

The Kenyan economy heavily depends on agricultural crops grown on natural rainfall. Agriculture contributes a significant share to the Country's GDP, employment, export earnings and provides income for many people especially in the rural agricultural areas. Maize is a key subsector in the agricultural sector. Maize as a crop covers the widest area under cultivation in relation to other crops in Kenya. It provides the Kenyan population with a third of their calorie intake and a key source of farm incomes especially in the maize surplus areas. Food security in Kenya and maize production are closely interlinked. At the country level, the availability of maize determines whether the country is food secure or not (Nyoro *et al.*, 2004).

Despite the importance of maize to the country, production especially in the last decade has been poor. The reasons for this include the high cost and increased adulteration of inputs, low and declining soil fertility, decreasing land sizes, limited access to affordable capital and low absorption of modern technology (Ministry of Agriculture, 2009). Besides the aforementioned factors, policymakers are waking up to the realization that, climate change is affecting maize production. Erratic weather conditions have been blamed for a succession of maize crop failures forcing the Kenyan government to import maize to feed its population.

Most studies (Kabubo-Mariara and Karanja, 2007; Downing, 1992; and Kabubo-Mariara, 2009;) conducted on the effects of climate change on agricultural sector in Kenya have analyzed the effects of climate on agriculture in general. Karanja (2006) mainly focused on the impact of temperature on production but failed to include the rainfall component. There is need to find out the effects of climate change on individual crops so as to be able to get a better understanding of effects of climate change on agricultural production in Kenya. The study sought to fill the gap in knowledge by giving insights on how climate change affects maize production with a focus on Uasin Gishu and Trans-Nzoia Counties.

1.3 Overall objective of the Study

The overall objective of this study was to assess the climate change impact on maize cultivation in Uasin Gishu and Trans-Nzoia counties.

1.3.1 Specific Objectives

The specific objectives of the study were:

1. To determine the nature of the variability and change in temperature and rainfall in Uasin Gishu and Trans-Nzoia counties.

2. To establish the relationship between production of maize and climatic elements in the two counties.

3. To establish challenges maize farmers face due to climatic change in the area under study.

4. To determine the economic impact of climate change on maize yield in UasinGishu and Trans-Nzoia counties.

1.3.3 Research Questions

This study was guided by the following questions:

1. What has been the pattern of the variability and change in temperature and rainfall in UasinGishu and Trans-Nzoia counties?

2. What is the link between maize yield and variations in climatic elements in UasinGishu and Trans-Nzoia counties?

3. In which way are maize farmers affected due to climatic change in the area under study?

4. What economic impact does climate change have on maize production in UasinGishu and Trans-Nzoia counties?

1.4 Research Hypothesis

The following hypothesis was tested in this study:

HO: There exist no significant relationship between maize yield and variations in climatic elements in UasinGishu and Trans-Nzoia counties

1.5 Study Significance

The results of the study provide important insights for policy formulation in the agricultural sector on the resultant effects of climate change on maize yield and food security in Kenya. Maize availability and food security in Kenya are closely intertwined. Lack of maize at the national silos and the household granary implies both the country and the households are food insecure. With this close relationship between food security of the country and maize production, it is important for policy legislators to have a candid understanding of the effects of climate change on maize production. The study also proposes adaptation options that could be taken up to reduce impact of climate change on agricultural produce. Finally, besides contributing to the pool of knowledge on climate variability, the study results forms a basis for further research.

1.6 Limitations of the Study

The researcher anticipated the language barrier limitation since some of the respondents who are farmers in the local regions were not in a position to communicate in English or Kiswahili. The researcher employed the use of translators who came in handy. The study was also limited geographically owing to the terrain of the region. The researcher had to navigate through the rough terrain of the region in order to be able to collect data. The researcher employed the services of locals who knew the two regions well. The study was limited in terms of the willingness of the respondents to participate in the study. Some respondents viewed the intentions of the research with a lot of suspicion. The researcher made clarity the purpose of the research to the participants and privacy of their responses assured.

1.7 Theoretical Framework of the Study

This study was based on two theories; Production Function Theory and Ricardian Theory.

1.7.1 The Production Function Theory

The production function theory advanced by Mendelsohn, et al., 1994 was the pioneering theory established the impact of climate change on agricultural activities. The theory is anchored on empirical production functions where environmental variables such as precipitation or temperature are inputs. These environmental variables in the production function are varied so as to establish the effects of climate change on yields. These variations in yields are incorporated in economic models so as to predicate the changes in welfare as an effect of climate change (Mendelsohn, *et al.,* 1994).

The Production Function Theory has the advantage of providing estimates of impact of climate that are free of bias as a result of the determinants of agricultural production that are beyond a farmer's control such as soil quality (Deschenes and Greenstone, 2006). In addition, the theory provides better predictions of climate change impacts on agricultural yields because of its use of controlled experiments (Mendelsohn et al., 1994; Deschenes and Greenstone, 2006). Despite this, the theory suffers from some limitations. First, the theory doesn't incorporate adaptation measures adopted by farmers. This is unlikely since farmers will respond to the changing climate conditions.

They may introduce new crops or replace crops with livestock. The lack of incorporation of adaptation measures results in an overestimation of damages as a result of climate change (Mendelsohn *et al.*, 1994). Secondly, the theory is very expensive because of the controlled experimentation required (Deressa, 2007). This may explains why the theory has been applied in few sites around the world and for a few crops mainly grains. Hence, the theory may be of little value for generalizing results.

1.7.2. The Ricardian Theory

This theory was propounded by Mendelsohn, Nordhous and Shaw in a study done in 1994 that examined the effects of climate change on USA’s agriculture. Mendelsohn, et al., (1994) developed this theory so as to counter-check the shortcoming that the production function approach had of over-estimating damages to agriculture because of climate change. This bias was a result of its failure to incorporate adaptation measures taken up in response to the changing climatic conditions.

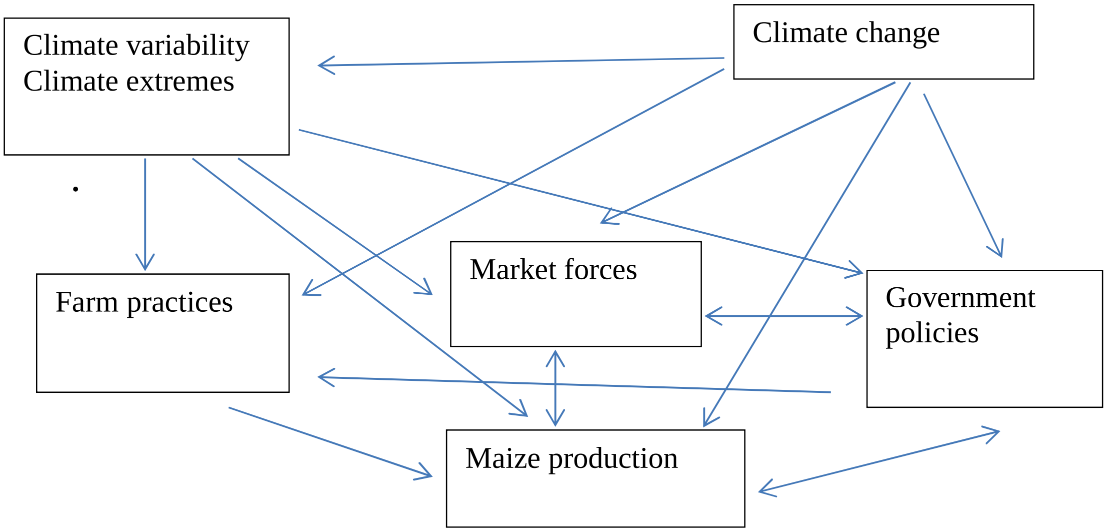
According to Mendelsohn, *et al*, (1994), the Ricardian Theory estimates the impact of climate change by looking at how climatic elements affects farm revenue or the value of the farmland. They note that by looking at the climatic elements such as temperature or precipitation on farm revenues or value of the farmland, the theory is able to incorporate farmer’s adaptations to climate change. This theory has gained popularity over the Production Function Theory in the recent past because of the various advantages it has over the Production Function Theory. First, it’s ability to automatically take into account the farmer’s adaptation responses and secondly, its cost effectiveness. This is because the Ricardian Theory can rely on secondary data whereas the Production Function Theory would require extensive experimentation which is expensive (Deressa, 2007*).*

However, the Theory suffers from some limitations. One limitation is that the Ricardian Theory fails to incorporate the transition costs a farmer may bear as a result of moving from one adaptation option to another due to climate change. For instance, when a farmer introduces a new variety of crop because of changing weather conditions, the theory assumes the costs due to change in type of new crop grown is borne by the farmer. However, if that new crop fails and the farmer introduces another new crop, the approach fails to capture costs associated with moving to other new crop. The transition costs could be quite high especially in agricultural subsectors where there is extensive capital used which can't be easily changed.

Another limitation is that the theory fails to account the effect brought about by variables that don't vary across space. For instance, the effects of carbon dioxide level which are generally the same across the world (Kurukulasuriya and Mendelsohn, 2008). Another weakness of the theory is that it is affected by aggregation bias. However, this weakness also affects other hedonic theories and is not restricted to the Ricardian theory only (Fezzi, *et al.,* 2010). Finally, the approach does not have control for the impact of important variables other than climatic factors that could explain the variation in land values or farm revenues.

1.7.3 Conceptual Framework

Figure 2.1 which identifies the independent and dependent variables of the study represents the conceptual framework. The framework conceptualizes interaction of climate change, farm practices, market forces, government policies and climate extremes as the independent variables and maize production as the dependent variable. The interaction is complex as shown in the fig 2.1 since at some point the government policies distorts market forces which in turn affects the amount of maize produced by farmers.


Climate variability
Climate extremes
Climate change
Market forces
Farm practices
Government policies
Maize production

CHAPTER TWO

2.0 LITERATURE REVIEW

Maize is grown throughout the world. The leading producer is the United States accounting for 40% of the world's harvest. France, Mexico, China, Brazil, Indonesia, India, and Argentina are among the top grain producing countries. By region, based on 2008 data, North America was the largest producer of maize accounting for 38.8% of the global output. Asia was second (28.5%); South America third (11.2%). Others were, Europe (11.1%); Africa (6.9%); Central America (3.4%); and Oceania (0.07%), in that order (Martinez, 2011).

In developing world, Argentina, Brazil and China produce over 60 percent of total maize output. China alone produces over 45 percent. White maize constitutes over 60 percent of the maize area in developing countries. However in developed world, white maize is of less significance. In the United States, the world’s largest maize producer, white maize cultivation accounts for less than one percent of the total maize produced (ibid).

Central America sub-region produces about 90 percent of total white maize output of the region excluding the Caribbean. The other part which produces white maize in plenty is the northern part of South America including Colombia and Venezuela. Other producers in Asia include China, Indonesia and the Philippines. Yellow maize is however produced more than white maize in these countries. In some areas of these countries, white maize seems to be the main staple food (Morris, 2014).

2.2 Maize Production in Africa

Maize was first brought to Africa by the Portuguese in the 16th to 18th century. Since then, it has become a stable food in Africa. South Africa, Tanzania, Uganda, Zambia and Swaziland produce most maize in East and Southern Africa. Major importers of maize were Zimbabwe, Angola, Ghana, Kenya and Mozambique. Several studies have shown that, due to increasing population, Kenya needs to increase maize production (Pingali, 2011).According to FAO/WFP 2004/2005 crop and food supply assessment, maize is in stable decline in its production. This was due to several challenges including delayed rainfall among other factors. The rain-fed agriculture is most vulnerable to climate variability.

Small-scale farmers produce most of the maize produ ced in Africa. Such small-scale farmers produce maize under very difficult conditions. The challenges include variation in environmental and climatic conditions, poor soils, and low-yielding seeds among others.Post-harvest losses are also another challenge the farmers are facing. Traditional granaries are used for grain storage in Africa. This leads to great post-harvest loss of maize grain. (International Maize and Wheat Improvement Centre, (IMWIC), (2010).

2.3 Agriculture and Climate Change in Sub-Saharan Africa

Maize produced in Africa is mostly done in small-scale farming and is rain-fed. Hence any climate variation affects the production in Africa (IPCC, 2010). Africa is experiencing high rate of temperature increase at the rate of about 0.05 degrees Celsius per decade. Rainfall in Africa has been delaying by one month but no corresponding change in rainfall cessation month. It is estimated that low rainfall will increase by 50 percent in the year 2100 in SouthernAfrica. The dry spell is bound to increase up to 30 percent over the Kalahari (ibid).

African countries are likely expected to feel the brunt of climate change due to poor adaptive measures.

2.4 Maize Production in Kenya

The major counties that are suitable for maize production are; Trans Nzoia, Uasin Gishu, Kakamega, Nakuru, Embu, Nyeri, Kirinyaga, Taita-Taveta and Kwale. The area under maize cultivation is estimated at a million and half hectares. An estimated 26 million bags of maize is produced every year. However this is below the annual domestic consumption of 34 million bags (Kamau, 2013).

It is government granaries that buy surplus maize during bumper harvest. It also regulates maize prices in the market. Other maize buyers are major millers within the neighbouring towns; these are Dola millers, Unga Millers, Mombasa Millers and Premier Millers. However the millers do not buy maize at good price. On average a Kenyan uses 98 kilograms of maize per year. Maize prices in Kenya are very prohibitive to consumers and poor household spends about 30% of their income on maize crop (Farm Management Handbook, 2007). Interventional measures can be adopted so that the maize subsector can contribute more to the economy. Some of these measures include enhanced production and efficient markets and government policies which supports the sector. With such reforms in place, the maize subsector can drastically reduce povertyin line with government policy of turning Kenya into newly developed middle-level income nation. Kenya has a deficit of about 400,000 to 700,000 metric tons which is bought from international market.

Small-scale farmers lack information on timely accurate market information. Other challenges faced by small scale farmers include poor storage facilities, poor roads to market placesall conspire to make the cost of food costly. Due to the liberalization of the maize sub-sector, most services which were once offered by the government have been withdrawn and have affected production.

2.5 Climate Change and Maize Production

The agro-climatic conditions include soil conditions and weather factors including humidity, rainfall and temperature. Human activities have interfered with the ecosystems more extensively in search of food, water, fuel and other raw material for industries (Mearns, 1995).

The impacts which come with Climate change include the pollution of the atmosphere, increased rainstorms, sea level changes, erratic rainfall and changing hydrological cycles. Other impacts include melting of snow and desertification.climatic change on agricultural crop have diverse effects which include change of crop type, soil moisture decreases due to evaporation, changes in growth stages of plants and spatial shifts of agricultural potential (ibid).

In Kenya, there is an already persistent food problem as a result of low yields. This has led to conflicts among communities due to water shortage. Species are also reducing leading to loss in biodiversity. Maize production in Kenya is affected by climatic factors such as amount of rainfall, variation in temperature, and humidity.

2.6 Challenges Maize farmers face due to Climate Change

In Kenya, climate change is a reality. For instance, there is an observed increase of mean annual temperature of 1^0C since 1960. The rainfall has gone down on average at the rate of 3.3% per decade. Changes in weather conditions such as drought and floods are expected to intensify in future.Food production, energy and water supplies will be affected by climate change.

These will impact negatively on the economic activities of people especially the poor rural folk. Attempts have been made to reduce the greenhouse gases and its negative impact on global warming. However these efforts have achieved little and the focus is on adaptive measures to the already damage done by climate change effects. There is little research on how climate change has impacted on maize farmers. The study at hand will establish the missing link by investigating on the effects of climate change on maize farming

2.7 Economic Impacts of Climate Change on maize Production

Mendelsohn, *et al.,* (1994) investigated effects of global warming on US agriculture by measuring the effects of climate change on land prices. The study used a Ricardian model and data which was cross-sectional in nature, farm prices and other economic data in United States. The study found that higher temperature in winter; spring and summer have an adverse effect on farm values while higher precipitation in all seasons except autumn increases farm values. It also found out that that higher winter and summer temperatures are harmful to crops while higher precipitation in spring and winter is beneficial. The study suggests the impact of climate change may be greatly overstated if analysis is limited to major grains.

Seo and Mendelsohn (2013) analyzed the effects of climate change on South American agriculture considering farmer's adaptation by measuring the changes of land values per hectare to seasonal temperatures and precipitation. They used a Ricardian model on information on climate, farmland crop prices and other economic variables for about 2300 farms from South America. The study used climate change data as predicted by three models namely the Atmospheric General Circulation Model, Canadian Climate Centre model and Parallel Climate model. The study found that agriculture in South American agriculture was vulnerable to climate change. Seo and Mendelsohn (2013) argue in their study that farm land values will decrease as temperature rises as well as when rainfall rises expect in the case of irrigation. The authors further argue in their study that large scale farms are highly affected by rainfall increases and small scale farms by increases in temperatures.

Deschenes and Greenstone (2006) studied the economic effects of climate changes on US agricultural sector .They used both a Ricardian model and also new strategy which they proposed where they estimated the impact of yearly changes in temperature and precipitation on US agriculture profits. The study used weather data drawn from the PRISM climate model, agricultural production data drawn from Census of Agriculture and soil data. The study found out that climate change will have a positive impact on US agriculture and agricultural profits will rise by 4%. The study suggested that the Ricardian approach is unreliable since it results can be easily be affected by small changes in control variables, sample or weighting.

Fezzi et al., (2010) investigated the impact of aggregation on the Ricardian model. The study used a ten year panel data set of 3000 farms covering the whole of Great Britain. The study found out that aggregation affects the climatic coefficients. The study suggested that predictions of climate change impacts based on the Ricardian model results may be wrong due to aggregation bias. The study also found out that increased temperature will adversely impact on land values if not accompanied by an increase in precipitation. Although the current study used the same approach as the studies by Mendelsohn, et al., (2014), Seo and Mendelsohn (2013), and Fezzi, et al., (2010) it has a number of differences from those studies.

First, those studies analyzed the effects of climate change on agriculture production while the current study looked at the impact on maize production. Secondly, those studies used farm land values as the dependent variable while the current study uses net farm revenue per hectare as dependant variable due to lack of data on farm values in Kenya. Molua and Lambi (2009) investigated the way in which climate change affects crop farming in Cameroon based on a cross-sectional survey of over 800 households. Climate data was sourced from secondary sources. In their analysis, the authors used the Ricardian approach and their results shows that temperature and precipitation had significant impact on Cameroonian crop farming. Increased temperatures according to their study had a negative impact on net farm revenues while increased precipitation had the opposite effect on farm net revenues.

Gbetibouo and Hassan (2011) investigated the effects of climate change on major field crops in the republic of South Africa using a Ricardian model. In their study, the authors regressed farm revenues on several variables including soil, climate, and other socio-economic variables from 300 districts in the republic of South Africa. Gbetibouo and Hassan (2005) found out in their study that temperature increase may have a positive impact while a reduction in rainfall may have a negative impact. The authors also suggest in their study that a shift in growing patterns and farming practices may occur.

Deressa (2010) investigated impact of climate change to the economy of Ethiopian. The study used farm data based on a survey of 1000 households which was conducted cross-sectionally in 50 districts covering 11 agro-ecological zones. The author found that climate change affects agricultural production in Ethiopia. According to the study, increased temperature not accompanied by an increase in precipitation will be damaging to Ethiopian agriculture.

Kabubo-Mariara and Karanja (2007) investigated the economic effects of climate change on Kenyan crop agriculture based on a cross –sectional survey of 816 households. The authors used a Ricardian method to investigate the effects of climate variables on net revenue per hectare. It was found that climate change affects agricultural productivity. The results indicated that high temperatures had negative effects on crop production while high precipitation had a positive effect. Their results indicated that medium and low potential agro-ecological zones were likely to be affected by climate change while high potential zones may actually gain from climate change. The study also found out farmers were conscious of the changing climate conditions and had started taking up measures to mitigate its effects. The results of above study were supported by another study by Kabubo-Mariara (2008) which investigated the effects of climate change on crop selection and measures taken to adapt to changing conditions by farmers.

The study used a probit model based on cross-sectional data to analyze the impact of climate change on crop selection and descriptive analysis to evaluate the adaptation measures being taken up by farmers. To analyze the impact of climate change on crop selection using the probit model, the crops were divided into major food crops, minor food crops and cash crops. The results of the study indicated the choice to grow a crop or a group of crops is affected by climate change. The results also showed that temperature has a bigger influence on the choice than precipitation. The study found out that for major food crops such as maize, the decision whether to grow or not was affected by both temperature and precipitation. Both temperature and precipitation also had a significant influence on decision to grow either tea or coffee, two major cash crops.

Kabubo-Mariara (2009) also investigated how climate change had affected production of livestock in Kenya. The author used a Ricardian model and found that livestock production in Kenya responds to climatic variation. The result shows that livestock incomes exhibit a nonlinear relationship with climate. The study found that a small increase in temperature may actually be beneficial to livestock productivity while increase in precipitation may have an adverse effect on it. According to the study, this was because high precipitation may result in farmers choosing to grow crops instead of keeping livestock. Although the current study used the same approach as the Ricardian studies, it differs in that it analyzes how climate change affects individual crop, maize, while the rest of the studies either focused on the impact either at whole agricultural sector, the crop agriculture sector or the livestock sector.

CHAPTER THREE

3.0 DATA, RESEARCH DESIGN AND METHODOLOGY

The chapter presents the data and the methods used for the objectives of the study to be achieved. It highlights the following elements: research design, sampling methods and procedure, data collection tools, data collection procedures and data analysis.

3.1 Data Types and Sources

The research adopted primary and secondary data. The former data was sourced from farmers in the study area using the questionnaires. Secondary data on climatic elements were sourced from Eldoret Meteorological Weather Station at Kapsoya estate and Kenya Agricultural and Livestock Research Station at Kitale town.

3.1.1 Research Design

The study used an explanatory survey design. This enabled the researcher to visit the region and seek responses from farmers in the two counties. The survey research design sought to identify the respondents by selecting the stakeholders in the maize farming activities. Research design measures variables by asking the respondents questions and then examines relationships among the variables. The research design helped to capture patterns of the questions being sought.

3.1.2 Research Site

This study was conducted in Uasin Gishu (figure 3.1) and Trans-Nzoia (figure 3.2) counties. Uasin Gishu is located within the former Rift Valley province. It spans between longitudes 34˚ 50’ East and 35˚ 37’ East and latitudes 0˚03’ South and 0˚ 55’ North. It covers an area of 3,345.2 Square kilometres. Uasin Gishu County has three zones namely; the upper highlands, upper midlands and lower highlands. UasinGishu

County lies in the Mid-West of the Rift Valley. The county borders the following counties including Trans Nzoia to the North, Elgeyo-Marakwet County on the Eastern, Baringo to the South East. Others include Kericho to the South, Nandi County on South West and Kakamega to the North West.

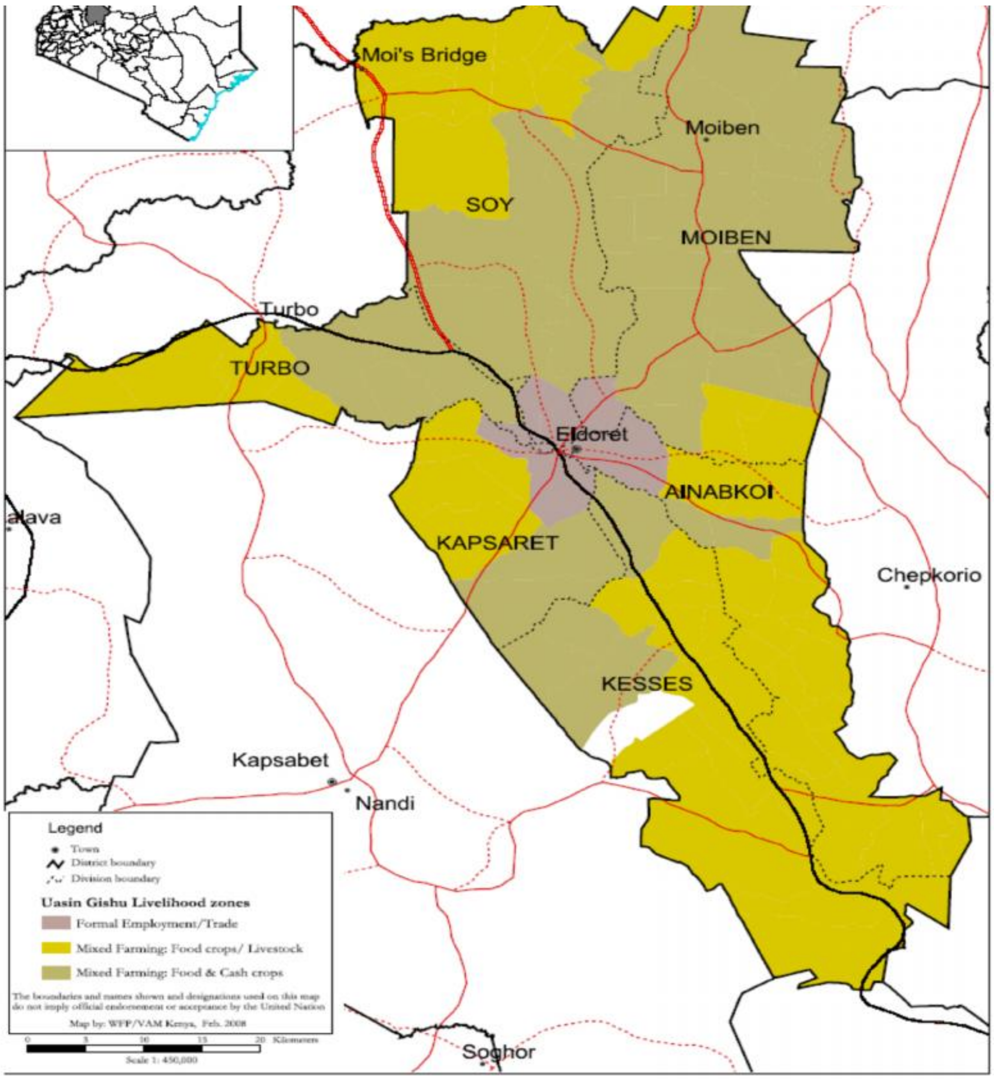


Figure 3.1: Map of UasinGishu County

Trans Nzoia County is located in the Northern Rift of Kenya. It borders the Republic of Uganda on the west, Bungoma and Kakamega counties on the South, West Pokot to the East, Elgeyo Marakwet and Uasin Gishu County to the South East. The County lies approximately between latitudes 0^0 52’ and 1^0 18’ North of the equator and longitudes 34^0 38’ and 35^0 23’ East of the Greenwich Meridian. The County headquarter is located at Kitale town. Other major centers in the county include Kiminini, Endebes, Kachibora and Sibanga (MailiNane).

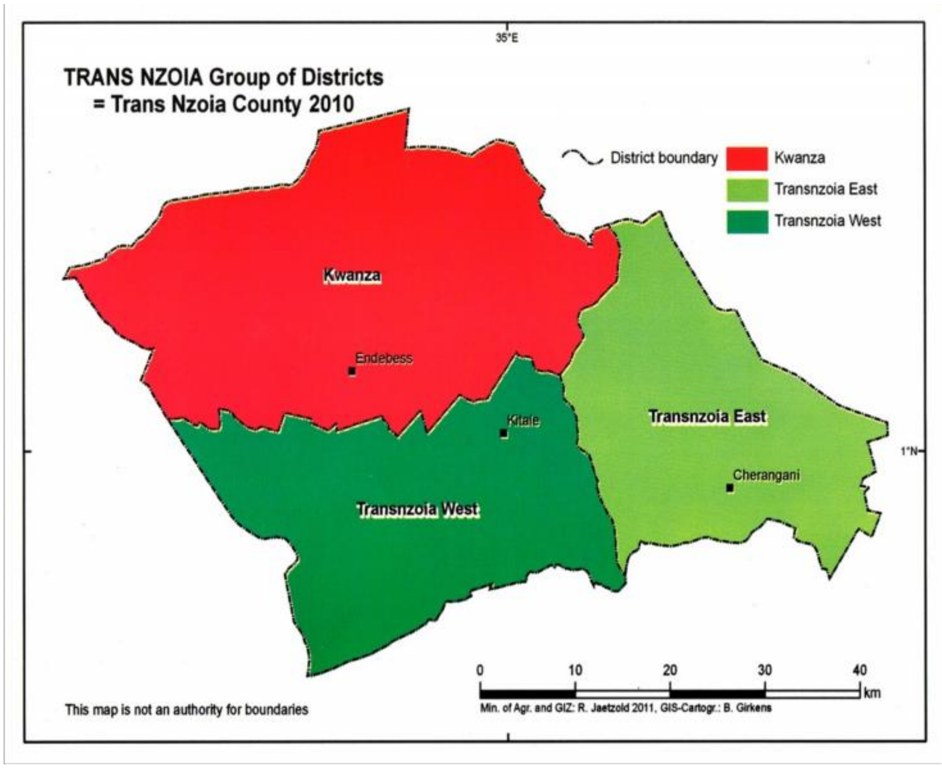


Fig 3.2: Map of Trans-Nzoia

3.1.3Target Population

The target population was large scale maize farmers in Uasin Gishu. Large scale farmers were preferred since the researcher wanted to rule out the impact of other factors other than climate change that may contribute to maize production. Such factors would include input, level of mechanization and modern knowledge on maize farming. The researcher assumed that all large scale farmers were homogeneous on these attributes. Periodic reports of Ministries of Agriculture in Uasin Gishu indicate that there are 744 large scale maize farmers in Uasin Gishu.

3.1.4: Sampling Techniques

A 30% proportion of the target population as provided for by Mugenda and Mugenda (2003) was computed to yield a sample size of 223 of large scale farmers in Uasin Gishu County. The sample size for these farmers was further computed proportionate to their population in the respective sub-counties (Table 3.1).

Table 3.1: Sample size in UasinGishu

Sub-county	Population of large scale farmer	Sample
Turbo	175	175 x 0.3 = 53
Soy	94	94 x 0.3= 28
Ainabkoi	114	114 x 0.3 = 34
Moiben	131	131 x 0.3 = 39
Kesses	108	108x 0.3 = 32
Kapseret	122	122 x 0.3=37
Total	**744**	**223**

3.1.5 Research Instruments

The researcher used the following instruments: questionnaire and interview schedules.

3.1.5.1 Questionnaire

Kothari (2006) describes a questionnaire as a list of questions printed or typed in a certain manner. Close-ended and open-ended questions were constructed. which were administered to the farmers in the study location. A questionnaire was used due to its low cost.

3.1.6 Validity of the instruments

This study ensured that the questionnaire was able to capture what it was intended to establish in the study. Questions were structured to suite the objectives of the study.

3.1.7 Reliability of the Instruments

Reliability is the consistency of an instrument in measuring what it measures.Pilot study data was used to calculate the reliability of the instruments'. The Pearson correlation of split forms was used to estimate the half test reliability after which the Spearman-Brown Prophecy Coefficient was computed to predict full test reliability based on the half test reliability using the formula below:

$$r_{sbi} = \left(Kr_{ij}\right)/1+\left(k-1\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where

sbi =The Spearman-Brown split half reliability

r_{ij} =The Pearson correlation between forms i and j

K=Total sample size divided by sample size per form (k is usually 2).

The instruments were split into two halves, the odd and even number criteria. Reliability was computed using the formula. A correlation of 0.80 or more indicates a well-constructed test. Pilot study results were used to compute the reliability coefficients as seen in (Table 3.2).

Table 3.2: Item Reliability Tests

Variable	Number of Items	Cronbach's Alpha
Nature of variability and change in temperature	9	0.8613
Maize production and climate change	5	0.8459
Challenges of climate change facing maize farmers	8	0.9234
Economic impacts of climate change on maize production	12	0.8765

3.1.8 Ethical Consideration Issues

The researcher agreed to fulfill the principle that individuals' privacy, confidentiality and dignity will be maintained. The subject was also informed of the aims and objectives of the study and that an individual will not be the subject of research.

At the tail end of the project, no information was included in the final report revealing the identity of the subject of the project.

3.2 Data Analysis

The study adopted both the qualitative and quantitative analysis techniques to achieve objectives of the study. Qualitative research employs interpretive techniques which normally describes or decodes the meaning of more or less naturally occurring phenomena in the social world. In quantitative techniques, inferential statistics was applied which dealt with making predictions about the properties of the population. Correlations were computed to identify relationships between study variables. The Ricardian Model was used to establish the economic impact of climate change on maize production.

3.2.2 Determination of the Nature of variability of Climate Elements

The parameters used for the analysis of the characteristics of climate climatic elements included, the mean, standard deviation, skewness, kurtosis, coefficient of variance and reliability.

The sample mean $\overline{X}$ is given by

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \quad \text{………………………………….} \qquad (3)$$

Sample standard deviation S,

$$S = \sqrt{\frac{\sum_{i=1}^{n} \left(X_i - \overline{X}\right)^2}{n-1}} \quad \text{………………………………………} \qquad (4)$$

Fisher –Pearson Coefficient of skewness q

$$q = \frac{\sum_{i=1}^{n} \left(X_i - \overline{X}\right)^3}{nS^3} \quad \text{………………………………………………} \ (5)$$

Excess Kurtosis

$$K = \frac{\sum_{i=1}^{n} \left(X_i - \overline{X}\right)^4}{nS^4} - 3 \quad \text{……………………………………..} \ (6)$$

3.2.2.1 Determination of the Trend

There are several statistical methods used to study the trend. The commonly used method is where the data is divided into two sets of equal period and to test the difference in the means of the two sets using t-test. This method was applied in the present study. The student t-test is expressed by equation,

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\pm_d^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7)$$

Where the difference in variance, $\pm_d$ is given by

$$\pm_d = \sqrt{\frac{\pm_1^2}{n_1} + \frac{\pm_2^2}{n_2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (8)$$

Where $\overline{x}_1$ and $\overline{x}_2$ are the means of two samples of sizes n_1 and n_2 of variances $\pm_1$ and $\pm_2$**,** respectively**.**

3.2.2.2 Cyclic Variation

One of the important questions is whether the extreme weather event exhibit cyclic variation. Most of the times meteorological data do have more than one cycle superimposed on each other which makes it difficult to identify them. However, there are certain statistical methods that are employed to identify hidden periodicity. One of these methods is spectral analysis.

3.2.2.3 Spectral Analysis

Spectral analysis is a new way of examining the hidden periodicities (cycles or oscillations) of any time series at certain frequencies. Other methods include the fast Fourier analysis method was used to detect cyclical variations of rainfall in this study. Spectral analysis has been used by many authors to examine cyclic variations. The spectral analysis density function $h(\mu)$ can be expressed as a Fourier transform of auto covariance function R (r). Thus

$$h(\mu) = \frac{1}{2\text{®}} \sum_{r=-\infty}^{\infty} e^{-i\mu r} R(r) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$- \pi \leq \omega \leq \pi$$

Where $\mu = 2\text{®} f$ is the angular frequency and f is the frequency and $i = \sqrt{-1}$.

In the normalized power spectrum $f(\omega)$, the auto covariance is replaced by autocorrelation, and takes form

$$f\,(\omega) = \frac{1}{2\text{®}} \sum_{r=-\infty}^{\infty} e^{-i\mu r} \circ (r) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (10)$$

In order to obtain consistent estimates of $f\,(\omega)$, smoothing functions ª (r) are used. The smoothed spectral density function, $f'(\mu)$, may be expressed as $f'(\mu) \leq \lambda(\mathrm{r}) f(\omega)$. Where $\text{ª}(r)$ is the smoothing weights or lag windows. Examples of lag windows that are used to smoothen the power spectrum are: Truncated Periodogram, Bartlett, Daniel, Tukey Humming, TukeyHunning, Parsen and Barklett–Priestley windows. The window employed in this study is the parsen window. This type of window is chosen because it is non-negative over the whole range of frequency and therefore avoids leakage of the power spectrum.

The parsen window is of the form.

$$\text{ª}(r) = 1 - 6\left(\frac{r}{M}\right)^2 + 6\left(\frac{|r|}{M}\right)^3, \qquad |r| \leq \frac{M}{2}$$

$$= 2\left(1-\frac{|r|}{M}\right)^{3}, \qquad \frac{M}{2} \le |r| \le M$$

$$= 0, \qquad |r| > M \qquad \text{………………………..} \ (11)$$

Where M is the truncation point. For practical purposes, $M \le \frac{N}{3}$,where N is the number of observations.

When the Parsen window is used, the smoothed normalized spectral density function, $f'(\text{µ})$is expressed in the following form.

$$f'(\text{µ}) = \frac{1}{2\text{®}}\left(1+2\sum_{r=1}^{m-1}\text{ª}\,(r)\right)\text{°}\,(r)\cos(r\text{µ}) \qquad \text{…………….} \ (12)$$

$$0 \le \omega \le \pi$$

The cycles appear as peaks in the graph of $f'(\text{µ})$versusω.

3.2.3 Determination of the Relationship between Maize yield and variations in Climatic Elements

3.2.3.1 Correlation analysis

This is the degree of relationship between two variables. The Pearson's correlation coefficient (r) was used to determine the correlation between the climate elements and the maize yield. Correlation coefficient is given by equation 13.

$$r = \frac{\sum_{i=1}^{N}(x_i - \overline{x})(y_i - \overline{y})}{\left[\sum_{i=1}^{N}(x_i - \overline{x})^2 \sum_{i=1}^{N}(y_i - \overline{y})^2\right]^{1/2}}$$ **... (13).**

Where

N =>Total number of observations

$\overline{x}$ =>Mean of the variable ‘x’representing first subset.

$\overline{y}$ =>Mean of the variable ‘y’representing second subset.

To test whether the correlation is significant, the student t-statistic was used. It is given by equation 14:

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$ ………………………………….. (14)

Where n is the number of observations

And r is the reliability coefficient.when the value for t =0.8 or more the correlation is significant.

3.2.3.2 Multiple regression analysis.

These are models that involve more than one independent variable and one dependent variable. This gave an analytical model which was used to develop a rainfall prediction model with respect to sunspot numbers. This relationship is given by the equation 15:

$\mathbf{Y=\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_kX_k}$ …………………………… (15)

Where; β's are coefficients Xi are the predictors, Y is the maize yield (predicted) and β_0 is a constant

3.2.4 Economic Impact of Climate Change on Maize Production

This study uses the Ricardian Approach to investigate the impact of climate change on maize production in Kenya. The Ricardian model is a cross sectional model that is used to evaluate the long term impacts of climate change on agriculture. The Ricardian model estimates the impact of climate change by looking at how climate affects farm revenue or the value of farmland. The model is based on Ricardo's idea that the land rent under competitive markets is the highest net income expected from it (Mendelsohn *et al.*, 1994). The model assumes that the value of farmland or the net farm revenue is the present value of future net revenue from farm related activities. Net farm revenue measures the net productivity and costs associated with individual crop or livestock (Kurukulasuriya *et al.*, 2007). Gross revenue values are ignored since empirical literature argues that they exaggerate the effect of climate (Mendelsohn *et al.*, 1994).

The Ricardian function following Mendelsohn et al. (1994) can be presented as equation 16;

$$R= (\Sigma PmQm\ (X, C, Z, S)-\Sigma PxX\ ) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

Where R is net farm revenue per hectare, Pm is the market price of maize, Qm is maize output, X is a vector of purchased inputs other than land, C is a vector of climate variables, Z is a vector of soil variables, S is the vector of the socio-economic variables and Px is the vector of input prices. The farmer is assumed to choose X to maximize the net farm revenue (R) given soil, climate and socio-economic variables. Maximizing net revenue in equation (16) subject to inputs leads to a reduced form

Ricardian model where net revenue (R) is a function of exogenous variables. These exogenous variables are C (climate variables), Z (soil variables) and S (the vector of the socio–economic variables). The reduced form Ricardian model takes up the general form as equation 17.

$$R= f(C, Z, S) \ldots\ldots \quad (17)$$

Equation 17 is said to follow a quadratic function with the climatic factors having squares in order to capture the nonlinear relationship between net revenue and climatic factors (Mendelsohn, *et al*., 1994). Therefore equation 18 is the estimated equation;

$$R=\beta o+\beta_1 C+ \beta_2 C^2 +\beta_3 Z+\beta_4 S +\mu \quad \ldots\ldots(18)$$

After estimating the Ricardian model, marginal impacts and elasticities are computed so as to assess the impact of climate change on maize production in Kenya. Marginal impacts show the change in net farm revenue as a result of unit change in the climate variables; temperature or precipitations (Mendelsohn, *et al.,* 1994) Marginal impacts for each climate variable are computed by differentiating equation (3) with respect to each climate variable; temperature and precipitation. The expected marginal impacts are given as equation 19.

$$E\ (\partial R/\partial C) = \beta_1+ 2\ \beta_2 *E(C) \ldots\ldots \quad (19)$$

Where R is the net farm revenue per hectare and C is the climate variable.

Elasticities are calculated so as to assess the relative change in net farm revenue per hectare associated with a unit change in temperature and precipitation. Elasticities are computed as follows;

Elasticity = $C/R\ (\beta_1 + \beta_2 C)$ ……………………………………......... (20)

Where R is the net farm revenue per hectare and C is the climate variable. β_1 and β_2 represent the coefficient for the linear and squared term of the climate variables.

The relationship between climate variables and net farm revenue per hectare was investigated using elasticity analysis. Elasticities are calculated at the mean so as to assess the relative change in net farm revenue per hectare associated with a unit change in temperature and precipitation (Gbetibouo and Hassan, 2015).

CHAPTER 4

4.0 RESULTS AND DISCUSSION

The results obtained using the methods described in the previous chapter are presented in the following subsections. The results include the nature of variability in the climatic elements, the connection between climatic elements and maize yield and the results on the analysis of the questionnaire on the challenges facing farmers with respect to maize production. The economic impacts of weather elements on maize yields have been presented.

4.1 Nature of Variability and Change in Temperature and Rainfall

The study sought to establish the nature of variability and change in temperature and rainfall in Uasin Gishu and Trans-Nzoia counties.

4.1.1 Nature of Variability and Change in Rainfall in UasinGishu

In order to detect changes in the climatic parameters the data was divided into two subsets and the statistical parameters computed. Table 4.1 provides the month by month comparison of the mean, standard deviation, skewness, kurtosis, coefficient of variability and reliability of rainfall at Eldoret for the two sub-periods. From the table it is clear that there has been a shift in the rainfall characteristics over the region. For example it can be seen that there has been an increase in the rainfall during the second half of the year which include the short rains season (OND). The rainfall during the first half of the year seems to have remained constant apart from April that shows a decrease. The reliability of rainfall has increased in May, August and October and decreased in the rest of the months. In most of the months, for example April, the skewness has changed from negative to positive implying a rise in the extreme rainfall events that often lead to flooding.

From table 4.1 it can be note that the rainfall at Eldoret has a tri-modal distribution with peaks in March-May, July-August and October-December seasons. The first two rainy seasons namely, March to May and July to August coincide with the maize growing period. The negative trend in table 4.1 shows that there has been decrease in the April rainfall. Table 4.1 show a positive trend in the July to August seasonal rainfall.

Figure 4.1 -4.3 show examples of the results of spectral analysis. The dominant peaks were observed at 2.2 to 2.8 years and 3.3 and 5 years which may be linked to Quasi Biennial Oscillation (QBO) and the El-Nino Southern Oscillation cycles respectively.

Table4.1. The temporal variation in the rainfall statistics over Eldoret

DATA SET		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUB-SET ONE	MEAN-1	22.24	33.81	73.87	149.01	126.53	97.69	150.82	150.49	67.98	41.25	68.83	25.83
	STD-1	23.86	39.50	52.04	54.67	74.33	38.33	46.74	76.16	31.65	33.13	55.29	28.37
	SKEW-1	0.69	2.17	0.64	-1.18	0.73	-0.24	-0.03	1.47	0.38	1.26	2.09	2.30
	KURT-1	-1.33	5.79	-0.18	0.64	-0.58	-0.53	-0.20	2.98	-0.34	1.71	5.72	6.79
	CV-1	107.26	116.83	70.46	36.69	58.75	39.24	30.99	50.61	46.55	80.31	80.33	109.84
	REL-1	-7.26	-16.83	29.54	63.31	41.25	60.76	69.01	49.39	53.45	19.69	19.67	-9.84
SUB-SET TWO	MEAN-2	42.78	36.78	70.41	129.81	120.92	107.07	173.51	161.28	80.96	86.34	62.61	53.81
	STD-2	57.97	51.85	50.91	86.40	58.42	52.57	68.85	59.14	58.42	60.39	61.45	69.51
	SKEW-2	2.52	1.70	1.14	1.17	0.14	0.34	1.22	0.43	0.63	0.09	0.93	1.17
	KURT-2	7.08	2.08	1.05	-0.16	-1.28	-0.45	1.17	-0.38	0.35	-0.98	-0.73	-0.37
	CV-2	135.50	140.99	72.30	66.56	48.31	49.09	39.68	36.67	72.16	69.95	98.15	129.18
	REL-2	-35.50	-40.99	27.70	33.44	51.69	50.91	60.32	63.33	27.84	30.05	1.85	-29.18
WHOLE SET	MEAN	32.82	35.34	72.09	139.12	123.64	102.52	162.51	156.05	74.67	64.48	65.62	40.24
	STD	45.34	45.59	50.68	72.31	65.61	45.75	59.38	67.07	47.11	53.50	57.72	54.72
	SKEW	2.99	1.82	0.85	0.53	0.54	0.28	1.10	1.01	0.85	0.77	1.31	1.79
	KURT	11.39	2.78	0.14	-0.38	-0.63	-0.19	1.82	1.47	1.32	-0.29	1.36	2.05
	CV	138.13	128.99	70.31	51.98	53.06	44.62	36.54	42.98	63.09	82.97	87.95	135.98
	REL	-38.13	-28.99	29.69	48.02	46.94	55.38	63.46	57.02	36.91	17.03	12.05	-35.98

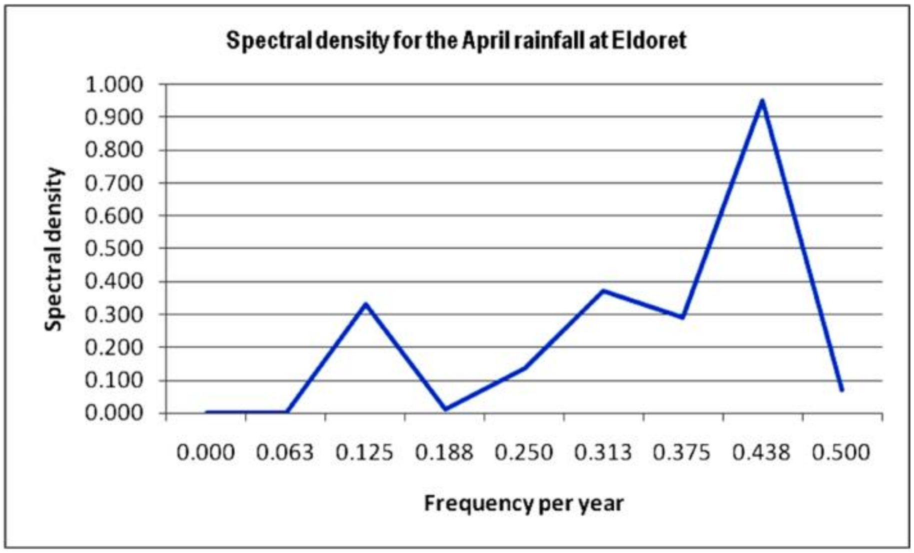


Figure 4.1: Spectral density of the April rainfall at Eldoret

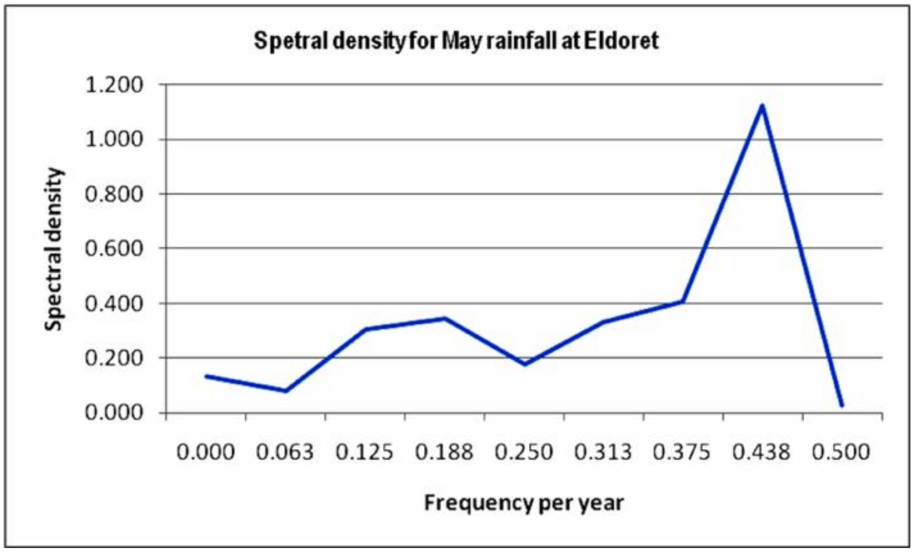


Figure 4.2: Spectral density for May rainfall at Eldoret

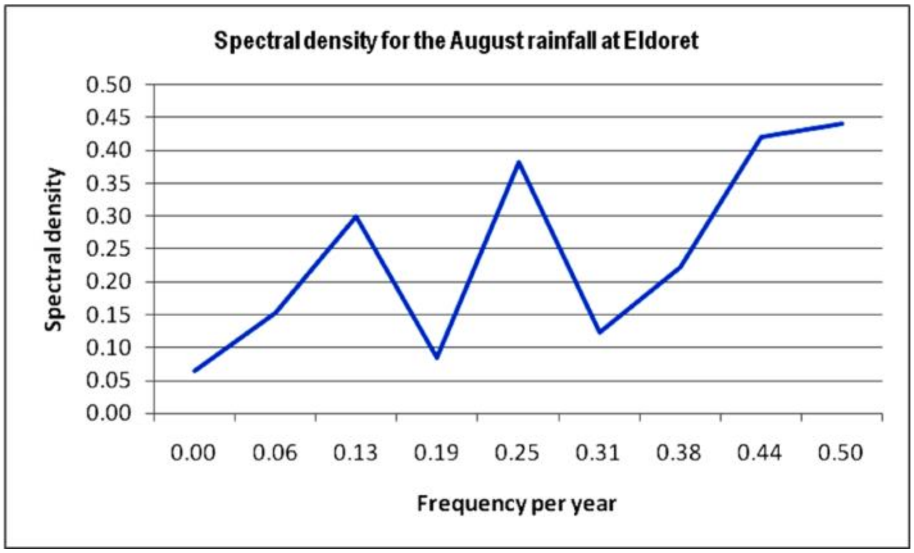


Figure 4.3 Spectral density for August rainfall at Eldoret

4.1.4 Nature of Variability and Change in Rainfall in TransNzoia County

Table 4.4 shows the month by month mean, standard deviation, skewness, kurtosis coefficient of variability and reliability of rainfall at Kitale during the two sub-periods and the whole period. From the table it is clear that there has been a shift in the rainfall characteristics over the region. Just like for the case of Eldoret, there is an increase in the rainfall during the second half of the year which include the short rains season (OND). The rainfall during the first half of the year show a decrease during February, March and May and increase in the other months.. The reliability of rainfall has increased in March, May, July, October and November and decreased in the rest of the months.

From figure 4.4 shows that the rainfall at Kitale has a tri-modal distribution with peaks in March-May, July-august and October-November seasons. The data on figure 4.5 indicate the reliability of the rainfall between April and August is quite high with reliability index of over 60%.The first two rainy seasons March to May and July to

August are separated by one dry month. In some year there is no marked rainfall cessation and the two seasons merge. The performance of the March to August rainfall is key to the maize production in this region. . Figure 4.6 show the peak rainfall month, April has a positive trend, while MAM the seasonal total rainfall indicate a negative trend (figure 4.7). On the other hand figure 4.8 show increased trend in the July-August rainfall.

Examples of the spectral analysis of the rainfall over Kitale are shown in figure 4.9 to 4.11. The dominant peaks were observed at 2.2 to 2.8 years, and 3.3 to 5 year and 10 to 11 years which may be linked to Quasi Biennial Oscillation (QBO), the El-Nino Southern Oscillation and sun spot cycles respectively.

Table 4.2 The temporal variation in the rainfall statistics over Kitale

DATA SET		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUB-SET ONE	MEAN 1	20.30	49.57	100.47	178.15	177.16	97.66	129.09	152.18	103.96	106.29	92.02	33.34
	STD	20.29	47.87	80.87	61.18	76.25	32.86	41.47	38.02	61.20	67.28	63.35	21.41
	SKEW	1.20	1.21	1.70	-0.06	0.64	0.37	-0.66	0.10	0.81	0.81	1.65	0.70
	KURT	0.65	0.54	4.03	-1.12	-0.41	-1.35	0.17	-1.53	-0.12	-0.01	3.45	0.14
	CV	99.94	96.57	80.49	34.34	43.04	33.64	32.12	24.99	58.87	63.30	68.84	64.21
	REL-1	0.06	3.43	19.51	65.66	56.96	66.36	67.88	75.01	41.13	36.70	31.16	35.79
SUB-SET ONE	MEAN 2	31.14	37.11	93.31	187.34	149.06	109.97	138.70	157.68	121.10	153.79	103.60	54.17
	STD	37.46	37.42	53.66	66.07	40.13	44.36	43.16	50.73	76.81	59.36	70.54	58.26
	SKEW	2.83	1.67	0.11	-0.16	0.53	0.06	-0.27	0.49	0.86	-0.10	1.42	1.99
	KURT	9.80	2.55	-1.14	-1.29	0.05	-0.83	-1.45	0.20	0.07	1.00	2.40	4.58
	CV	120.30	100.86	57.51	35.27	26.92	40.34	31.12	32.17	63.43	38.60	68.09	107.55
	REL-2	-20.30	-0.86	42.49	64.73	73.08	59.66	68.88	67.83	36.57	61.40	31.91	-7.55
WHOLE SET	MEAN	25.87	43.34	96.79	182.87	162.71	103.99	134.03	155.01	112.77	130.72	97.98	44.05
	STD	30.42	42.78	67.31	62.97	61.19	39.13	42.01	44.44	69.20	66.88	66.41	44.99
	SKEW	2.94	1.39	1.39	-0.09	1.01	0.28	-0.41	0.43	0.89	0.21	1.47	2.58
	KURT	11.98	1.11	3.64	-1.22	0.90	-0.79	-0.70	-0.02	0.15	-0.49	2.29	8.81
	CV	117.58	98.71	69.55	34.43	37.61	37.63	31.34	28.67	61.36	51.16	67.79	102.13
	REL	-17.58	1.29	30.45	65.57	62.39	62.37	68.66	71.33	38.64	48.84	32.21	-2.13

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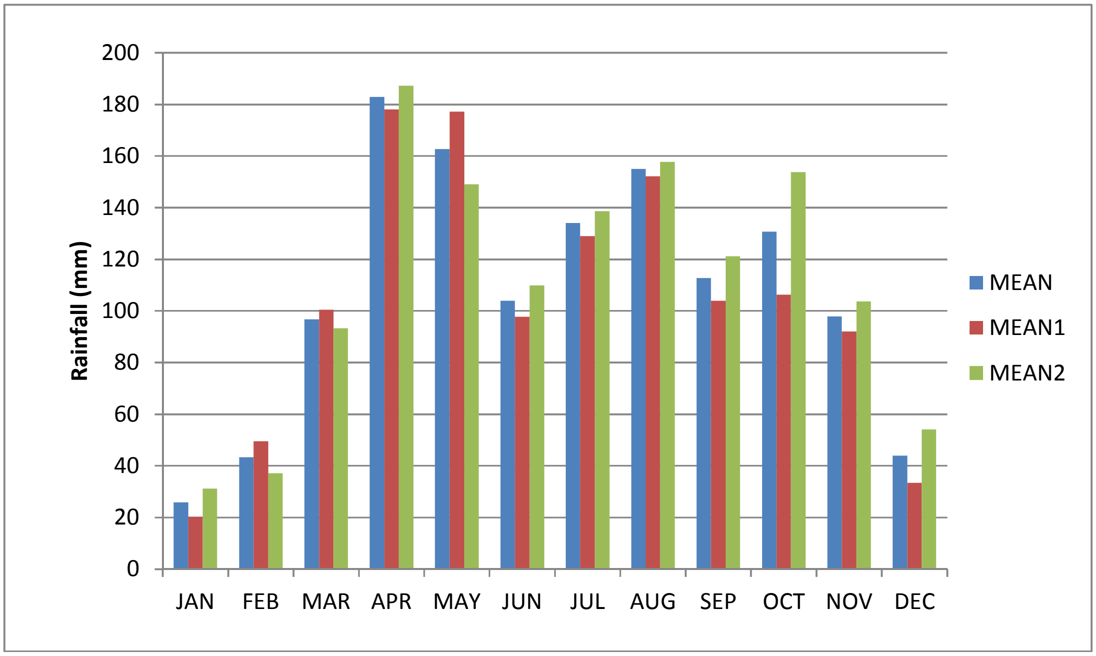

Figure 4.4 Comparison of the mean rainfall over the whole period and over the two sub-periods over Kitale

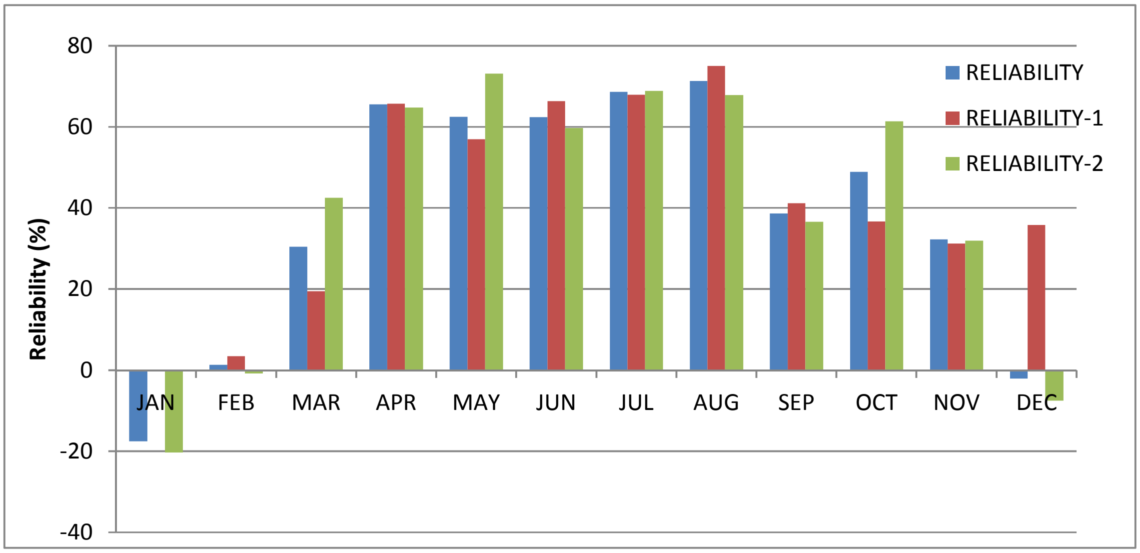

Figure 4.5 Comparison of the reliability of rainfall over the whole period and the two sub-periods over Kitale

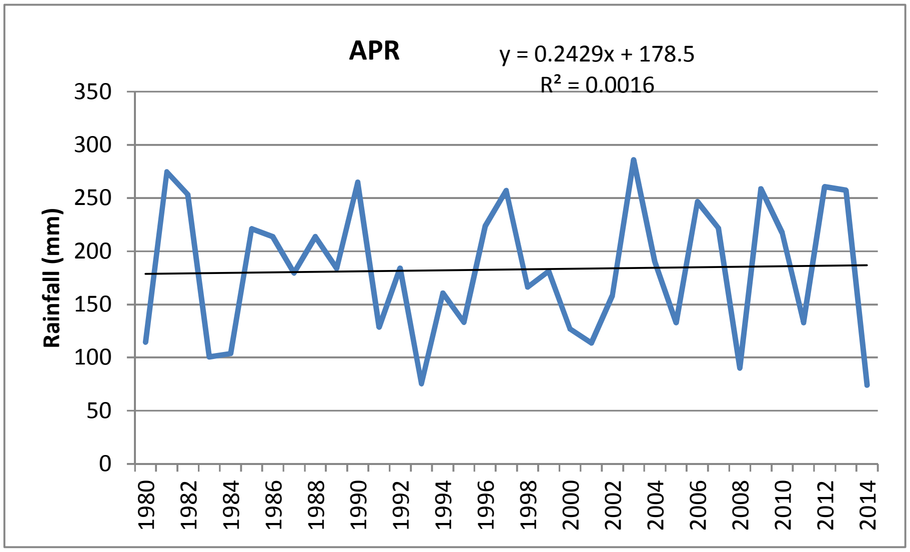

Figure 4.6 Time series of the April Rainfall at Kitale

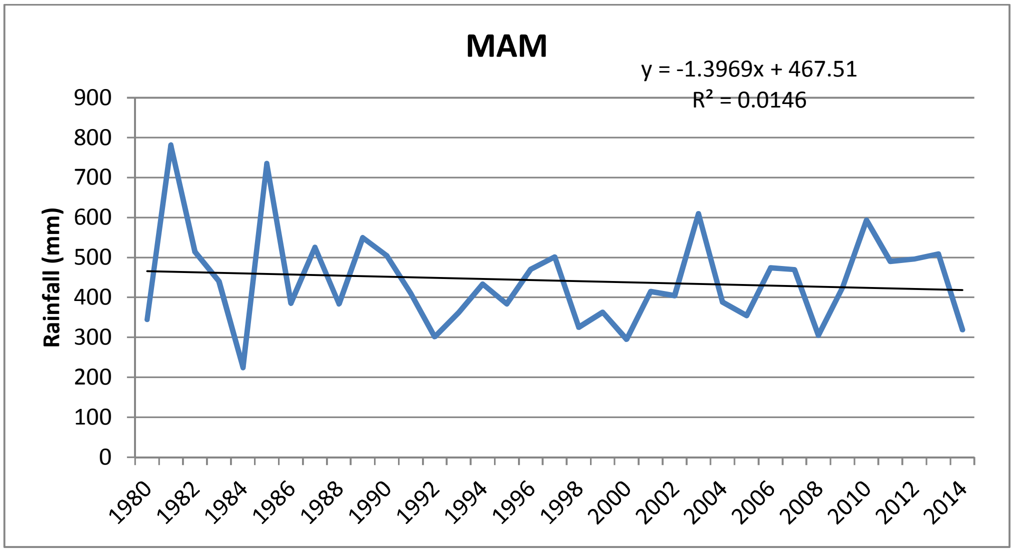

Figure 4.7 Time series of the March to May (MAM) Rainfall at Kitale

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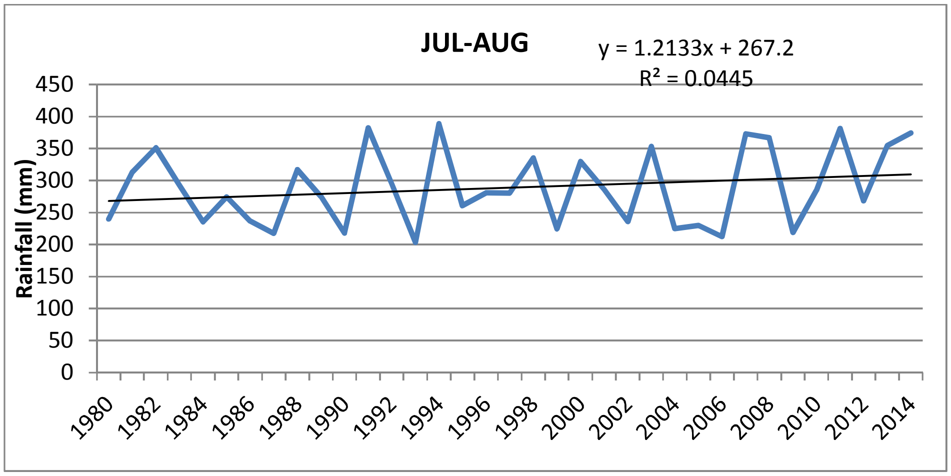

Figure 4.8 Time series of the July to August Rainfall at Kitale

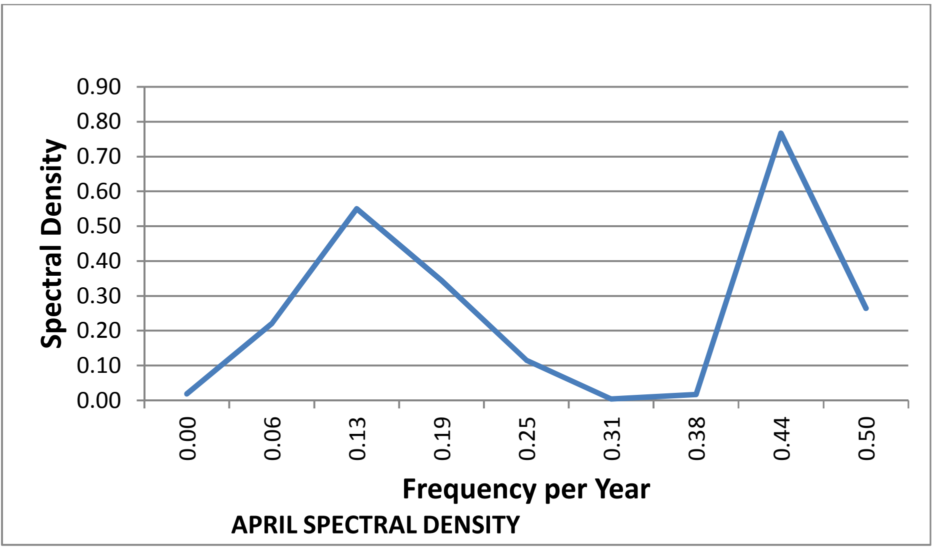

Figure 4.9 spectral density for the month of april

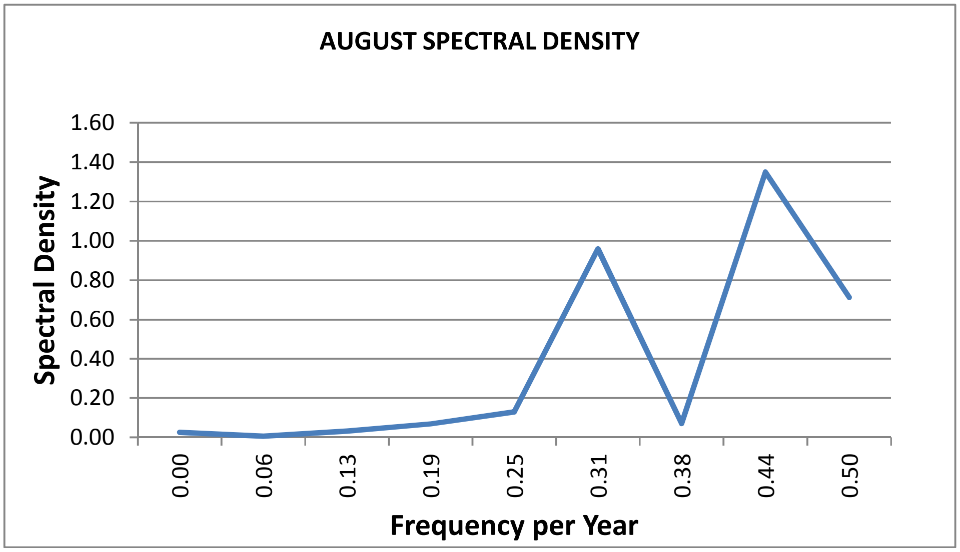

Figure 4.10 spectral density for the month of august

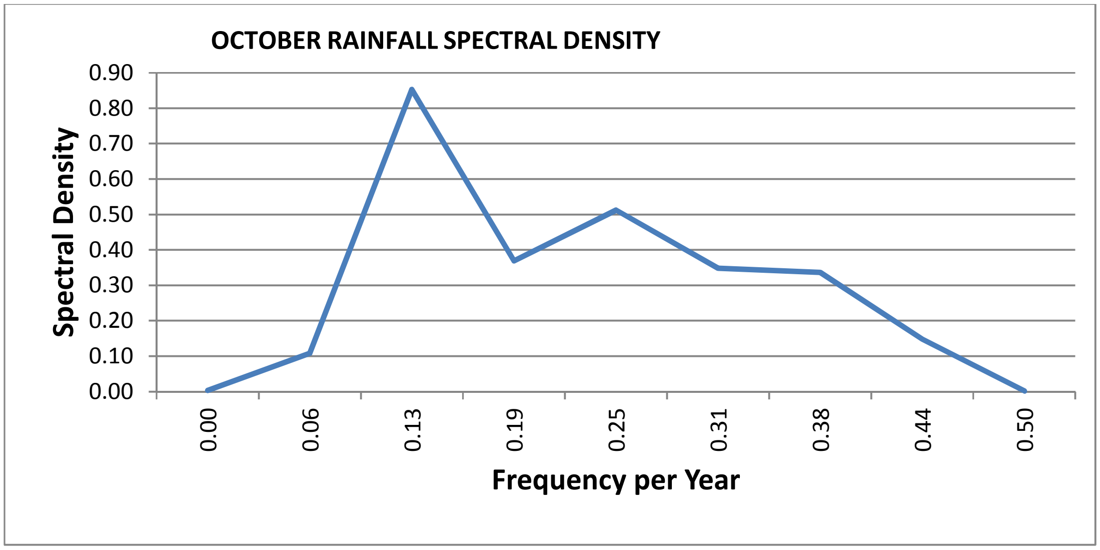

Figure 4.11 spectral density for the month of October.

4.1.2 Nature of Variability and Change in Maximum Temperature in Uasin Gishu

Table 4.2 provides the comparison of the mean, standard deviation, skewness, kurtosis coefficient of variability and reliability of maximum temperature at Eldoret for the two sub-periods. From the table there seem to be minimal shift in the characteristics of maximum temperature over the region. The coefficient of variability is less than 10% for all the months. There is a general increase in the mean maximum temperature for all months except January, February and November. The decrease in the January and February temperatures may be linked with the increase in cloud cover during the two months associated with the rise in the frequency of ENSO which cause the short rains to extend to January and February. Figure 4.12 show that March is the warmest month while July is the coldest month. The trend analysis indicated a negative trend for most of the months including annual mean (Figure4.13, 4.14 and 4. 15). These trends were however not significant.

The result from spectral analysis of the maximum temperature show that the warm months like February and annual were dominated by the low frequency cycles (Figure 4.16 and 4.18). This low frequency may be attributed to the presence of the trend in the maximum temperature. Besides the low frequency cycles the other cycles that were evident included 2.2-2.8, 3-5, and 10-12 year which may be associated with QBO, ENSO and sunspots respectively. The colder months like July (Figure 4.17), however displayed moderate and high frequency cycles which are associated with the variability in the atmospheric and oceanic variability. .

The temperatures over this region, are affected by among other factors, the regional radiative processes, together with the main systems operating and controls the spatial and temporal characteristics of climate of the region. These include Inter-tropical Convergence Zone (ITCZ), Monsoon Wind System and Sub-Tropical Anti-Cyclones. The climate of this region is also affected by the regional and large-scale quasi-periodic climate system like the Quasi-Biennial Oscillation (QBO), Intra-Seasonal Waves and El-Nino-Southern Oscillation (ENSO).

Table 4.3 The temporal variation in the maximum temperature statistics over Eldoret

DATA SET		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUB-SET ONE	MEAN-1	24.72	25.41	25.45	23.85	22.79	22.02	22.14	21.92	23.11	23.70	23.02	23.05
	STD-1	0.99	1.28	0.83	1.22	0.81	0.81	1.32	0.53	0.95	1.00	0.63	1.03
	SKEW-1	-1.59	0.14	-0.71	0.28	0.50	-0.22	2.83	0.61	1.69	0.44	-0.53	-0.36
	KURT-1	4.04	0.66	0.74	-0.33	1.82	-0.37	9.49	0.39	3.33	-0.64	-0.04	0.32
	CV-1	3.99	5.03	3.28	5.10	3.55	3.66	5.96	2.44	4.09	4.23	2.73	4.47
SUB-SET TWO	MEAN-2	24.07	25.02	25.47	24.22	23.09	22.60	22.20	22.60	23.66	23.70	22.79	23.25
	STD-2	1.13	2.00	1.08	0.83	0.77	0.91	0.88	1.12	1.05	0.71	0.85	0.94
	SKEW-2	-1.02	-2.95	-0.49	0.30	-0.92	-0.58	-0.12	1.37	-0.22	1.06	0.17	-0.29
	KURT-2	0.33	9.97	-0.27	-1.08	0.18	-0.28	-0.21	1.84	-0.03	1.54	-1.48	-0.41
	CV-2	4.71	7.98	4.24	3.44	3.33	4.04	3.96	4.95	4.45	3.02	3.74	4.06
WHOLE SET	MEAN	24.41	25.22	25.46	24.03	22.94	22.30	22.17	22.25	23.38	23.70	22.91	23.14
	STD	1.10	1.65	0.95	1.05	0.79	0.89	1.11	0.92	1.02	0.86	0.74	0.98
	SKEW	-1.16	-2.40	-0.54	0.08	-0.14	-0.23	2.17	1.77	0.61	0.59	-0.18	-0.34
	KURT	1.13	9.80	0.01	-0.31	0.21	-0.61	7.79	4.10	0.01	-0.07	-1.08	-0.10
	CV	4.49	6.55	3.72	4.36	3.45	4.01	5.01	4.14	4.37	3.64	3.24	4.23

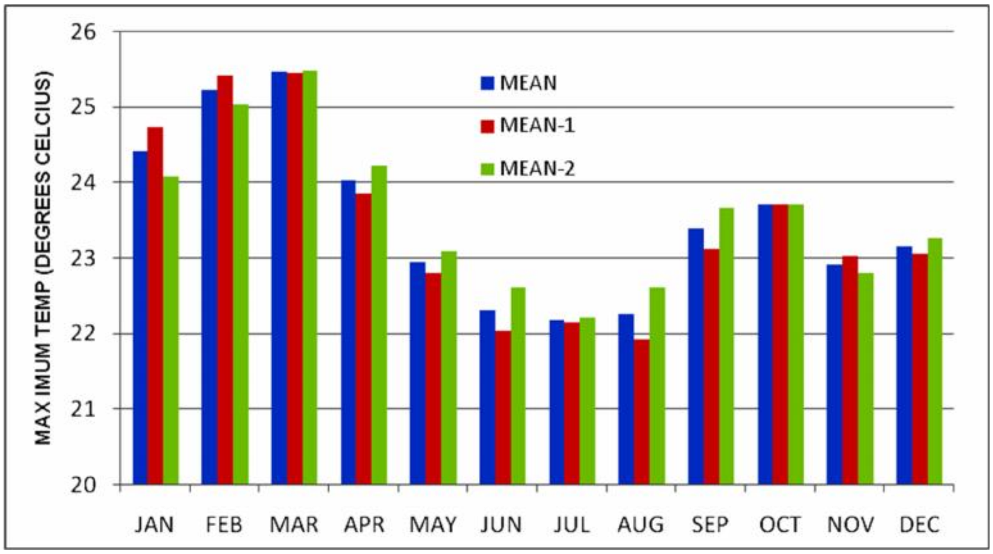

Figure 4.12 Comparison of the mean maximum temperature over the whole period and over the two sub-periods over Eldoret

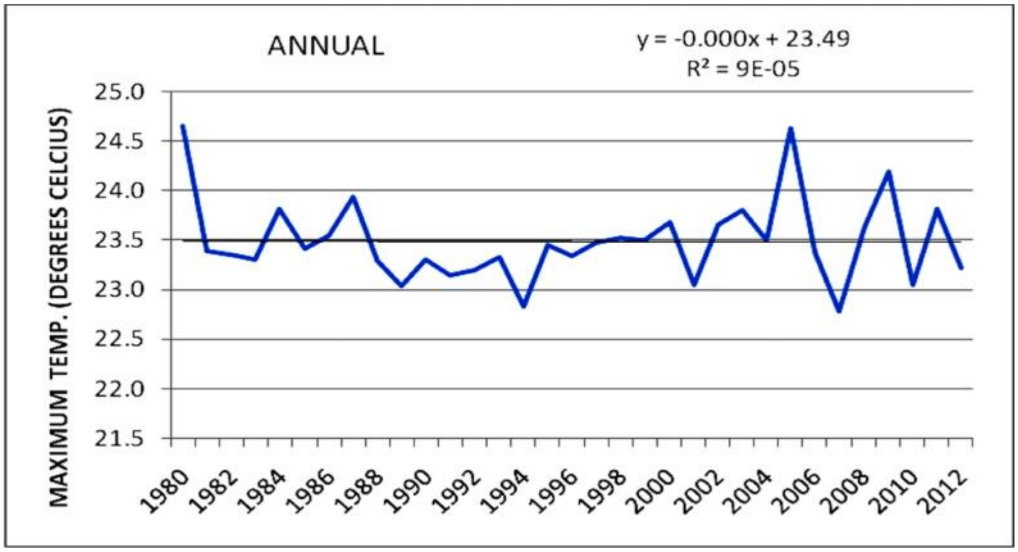

Figure 4.13 the time series of the mean annual maximum temperature at Eldoret

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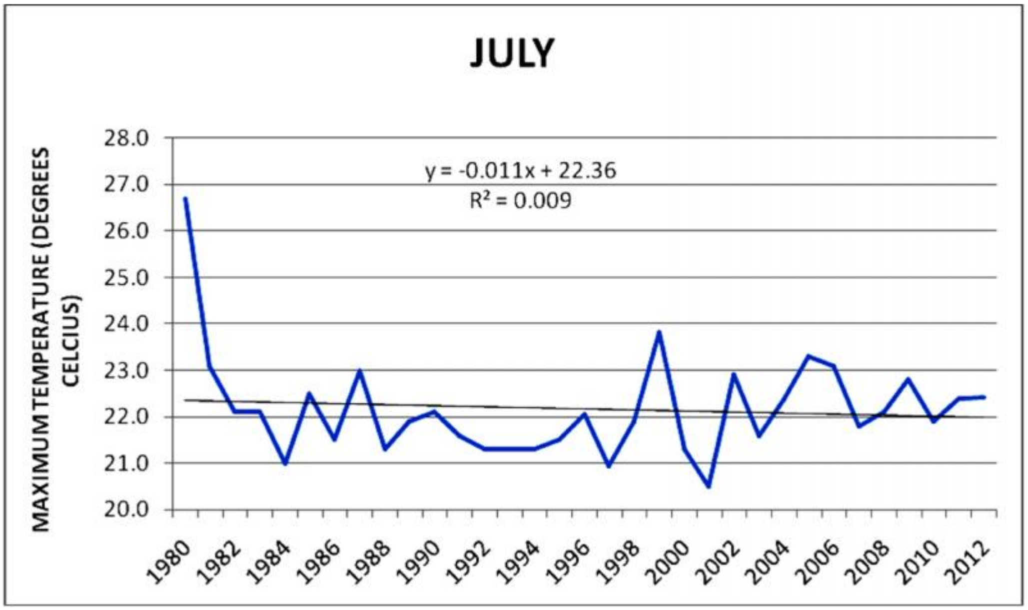


Figure 4.14 Time series of the July maximum temperature at Eldoret

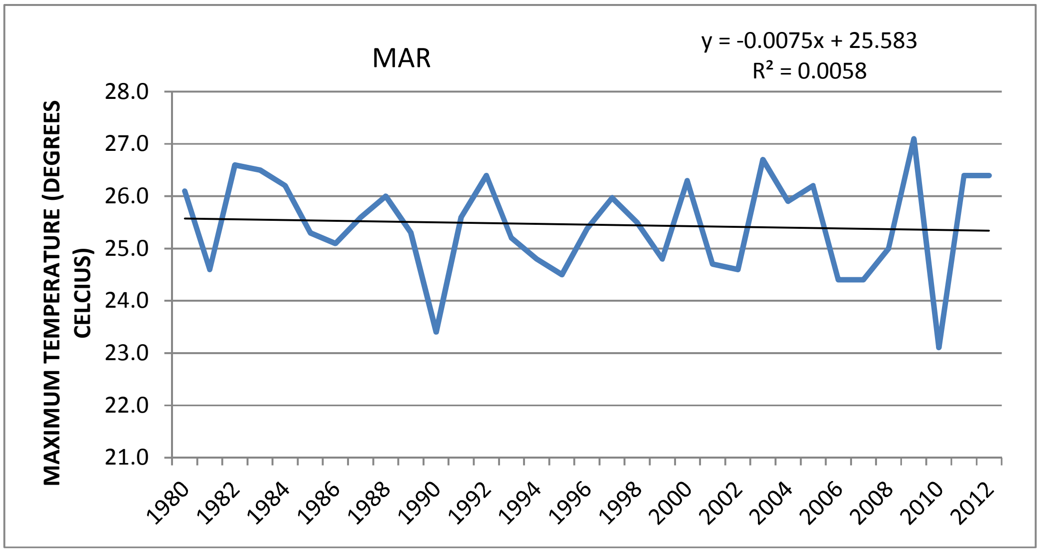


Figure 4.15 Time series of the March maximumtemperatureatEldoret

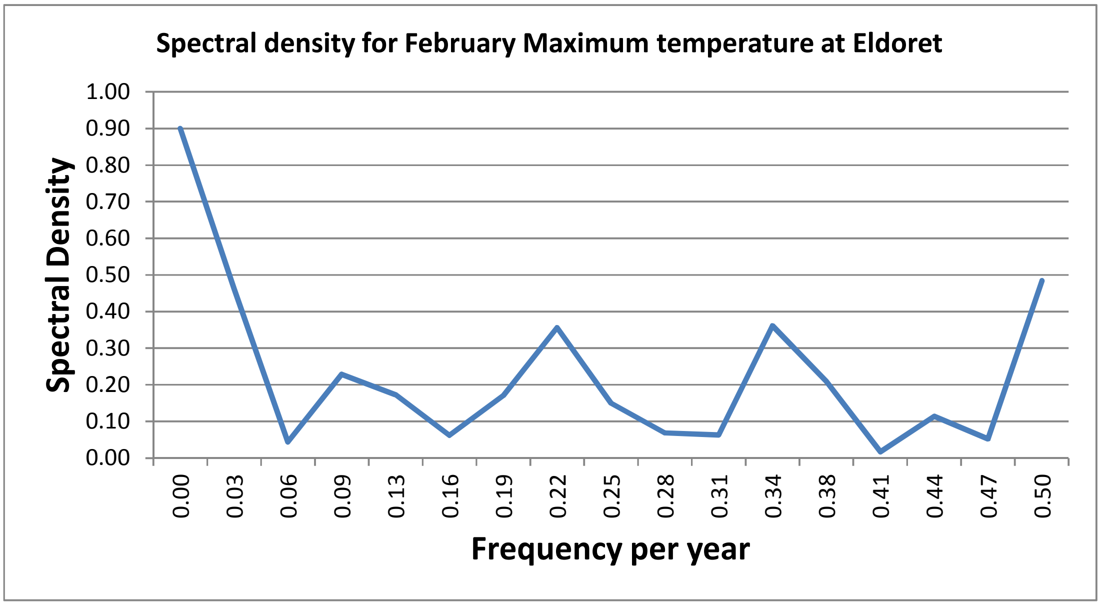


Figure 4.16 Spectral density for February Maximum temperature at Eldoret

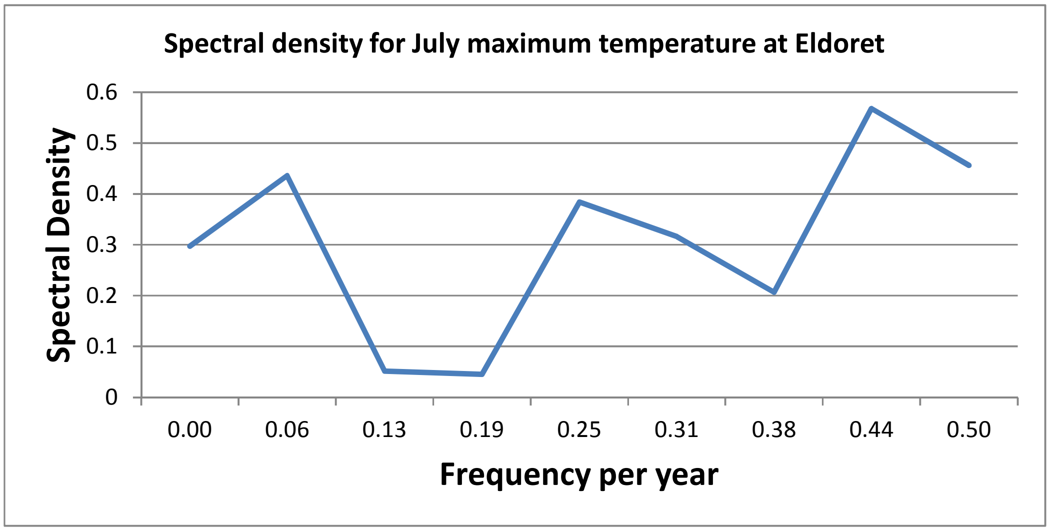


Figure 4.17 Spectral density for July Maximum temperature at Eldoret

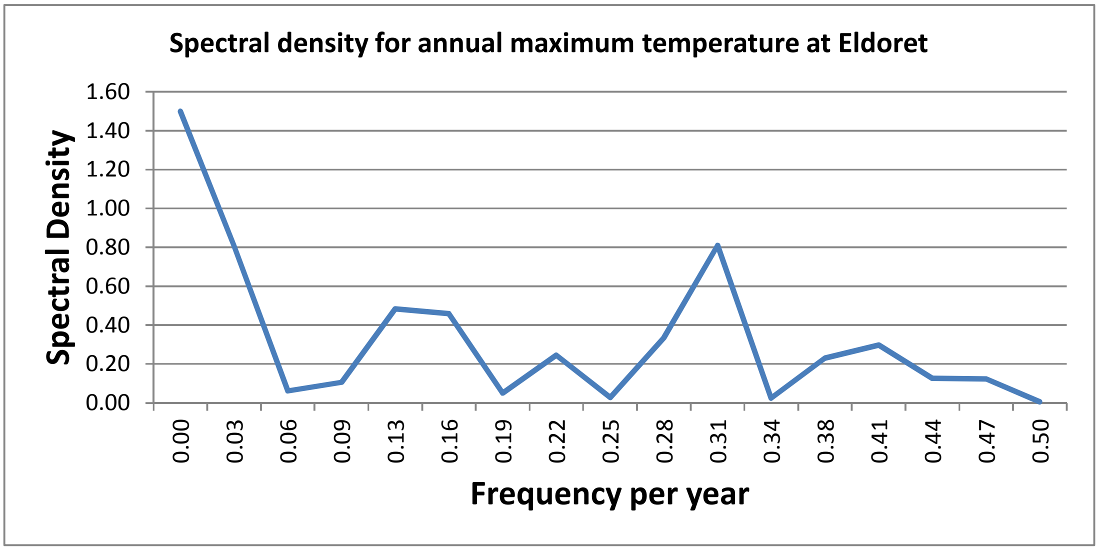


Figure 4.18 Spectral density for annual Maximum temperature at Eldoret

4.1.5 Nature of Variability and Change in Maximum Temperature in Trans-Nzoia County

Table 4.5 provides comparison of the mean, standard deviation, skewness, kurtosis coefficient of variability and reliability of maximum temperature at Kitale for the two sub-periods. For the overall period it is noted that the temperature is highest during the first quarter of the year. Apart from January, February, June and November the rest of the months indicate positive skewness. Positive (negative) skewness indicates high frequency of occurrences above (below) the mean. The highest coefficient of variability was observed during the warmer months. On comparing the two sub-periods it was noted that there is a general increase in the mean temperature over most of the months. Figure 4.19 shows the annual cycle of the maximum temperature, from it we note that March is the warmest month while July is the coldest month. Figures 4.20 to 4.22 show the time series for the annual, February and July maximum temperature. Positive trend is evident in all the three cases. These trends were tested and found to be significant.

Figures 4.23 to 4.25 show the spectral density for annual, February and July maximum temperature. The annual has the highest peaks with the low frequency which is a manifestation of the trend as the main variability of the annual temperature. Nevertheless there are smaller peaks at 6.4year, 3.6years and 2.5 years. Both February and July have peaks at 32year, 8 years, 3.6 and 2.5 years.

Table 4.4 the temporal variation in the maximum temperature statistics over Kitale

DATA SET		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUB-SET ONE	MEAN-1	27.56	28.32	28.18	25.99	25.19	24.45	23.68	24.19	25.43	25.58	25.20	26.14
	STD	1.17	1.43	1.09	1.09	0.57	0.67	0.63	0.62	1.08	0.72	0.61	0.90
	SKEW	-0.15	-0.63	0.04	0.12	0.38	-0.54	1.77	0.24	0.27	0.05	-0.10	0.37
	KURT	0.60	-0.03	-1.08	-1.04	-0.83	0.35	4.23	1.78	1.94	-0.73	0.72	-0.33
	CV	4.24	5.05	3.88	4.18	2.28	2.73	2.65	2.57	4.25	2.83	2.41	3.44
SUB-SET TWO	MEAN2	27.57	28.79	28.49	26.73	25.80	25.01	24.50	24.81	25.69	25.84	25.54	26.46
	STD	1.14	0.90	1.14	0.82	0.43	0.57	0.77	0.56	0.46	0.57	0.70	0.83
	SKEW	-1.64	-0.51	-0.22	0.32	0.50	0.32	-0.35	-0.26	0.19	-0.20	-0.38	0.00
	KURT	2.72	-1.34	-0.95	-0.65	-0.52	1.16	-1.22	-0.86	-0.62	-0.94	-1.06	0.41
	CV	4.12	3.12	4.01	3.06	1.66	2.29	3.16	2.25	1.81	2.22	2.75	3.14
WHOLE SET	MEAN	27.56	28.32	28.18	25.99	25.19	24.45	23.68	24.19	25.43	25.58	25.20	26.14
	STD	1.17	1.43	1.09	1.09	0.57	0.67	0.63	0.62	1.08	0.72	0.61	0.90
	SKEW	-0.15	-0.63	0.04	0.12	0.38	-0.54	1.77	0.24	0.27	0.05	-0.10	0.37
	KURT	0.60	-0.03	-1.08	-1.04	-0.83	0.35	4.23	1.78	1.94	-0.73	0.72	-0.33
	CV	4.24	5.05	3.88	4.18	2.28	2.73	2.65	2.57	4.25	2.83	2.41	3.44

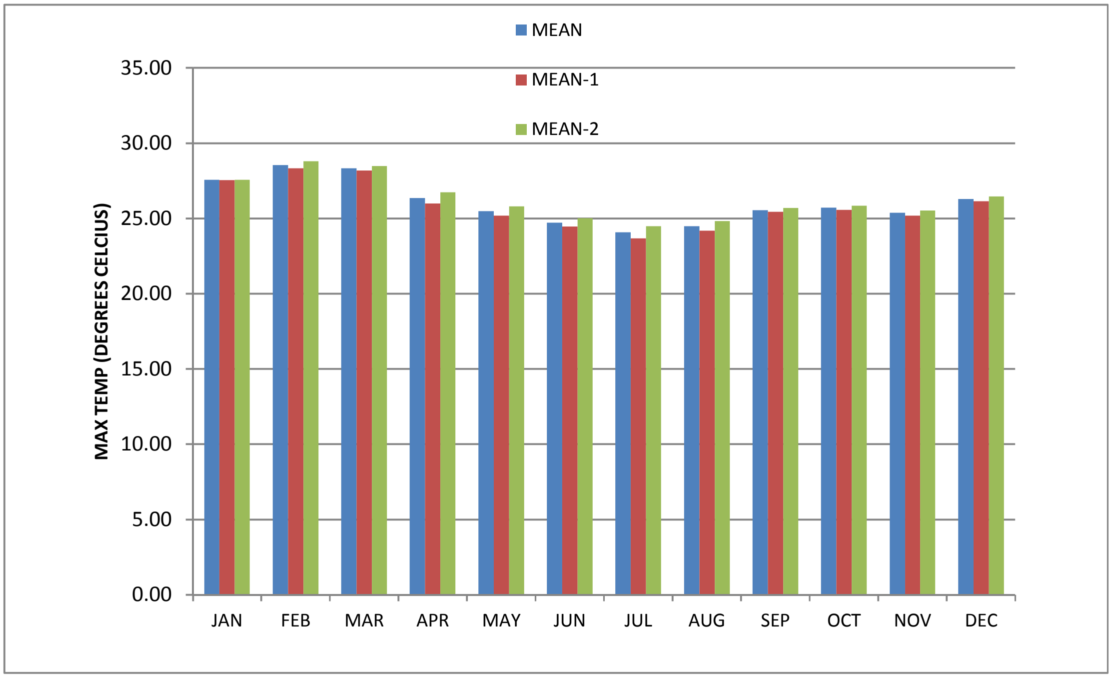


Figure 4.19 Comparison of the mean maximum temperature over the whole period and over the two sub-periods over Kitale

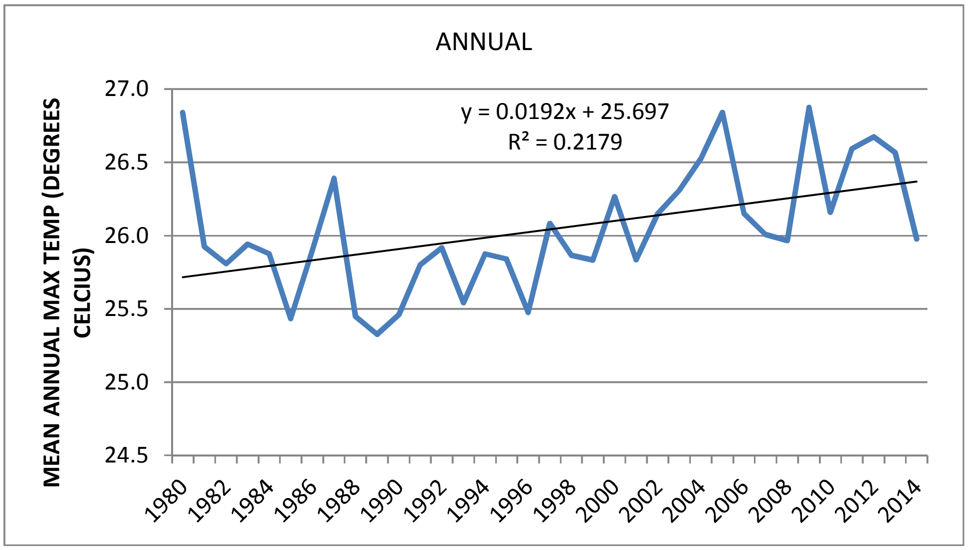


Figure 4.20 the time series of the mean annual maximum temperature at Kitale

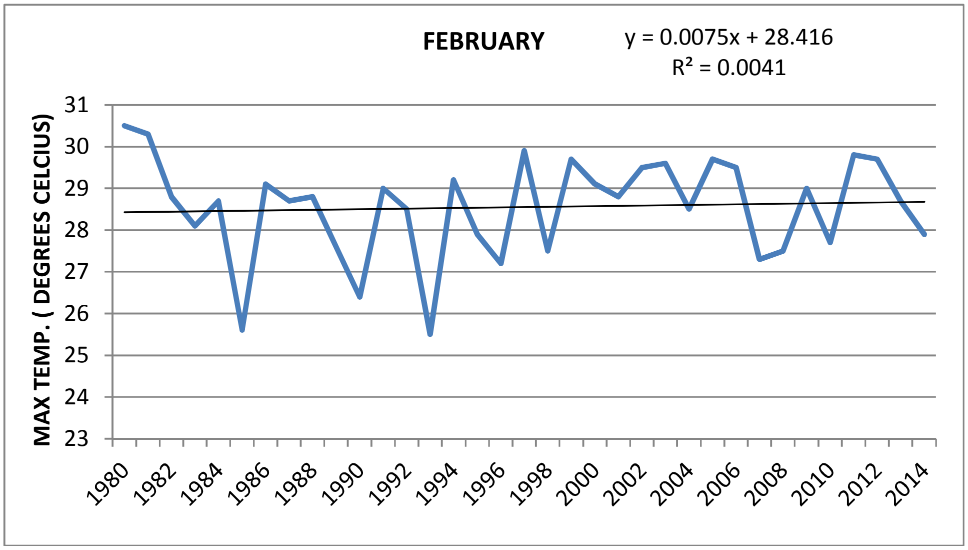


Figure 4.21 Time series of the February maximum temperatures at Kitale

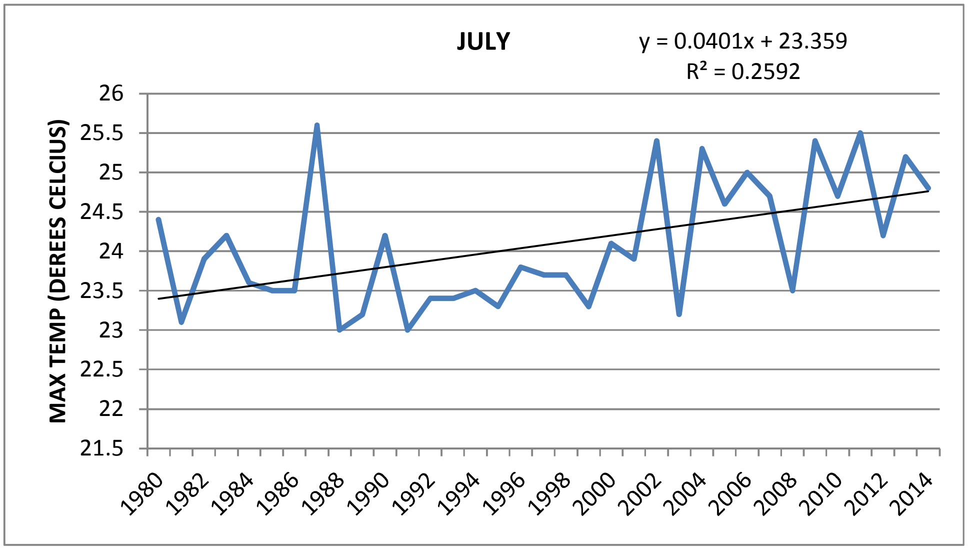


Figure 4.22 Time series of the July maximum temperature at Kitale

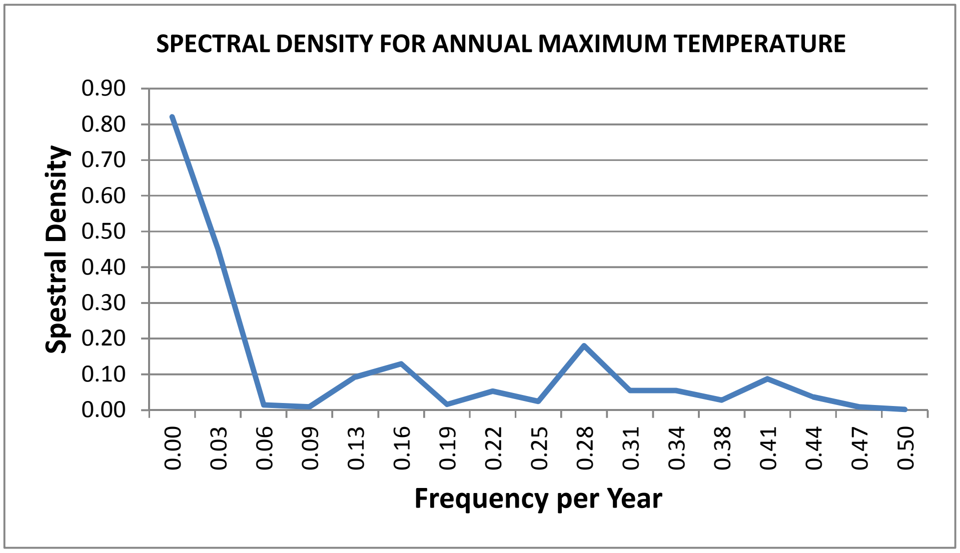


Figure 4.23 spectral density for annual maximum temperature over Kitale

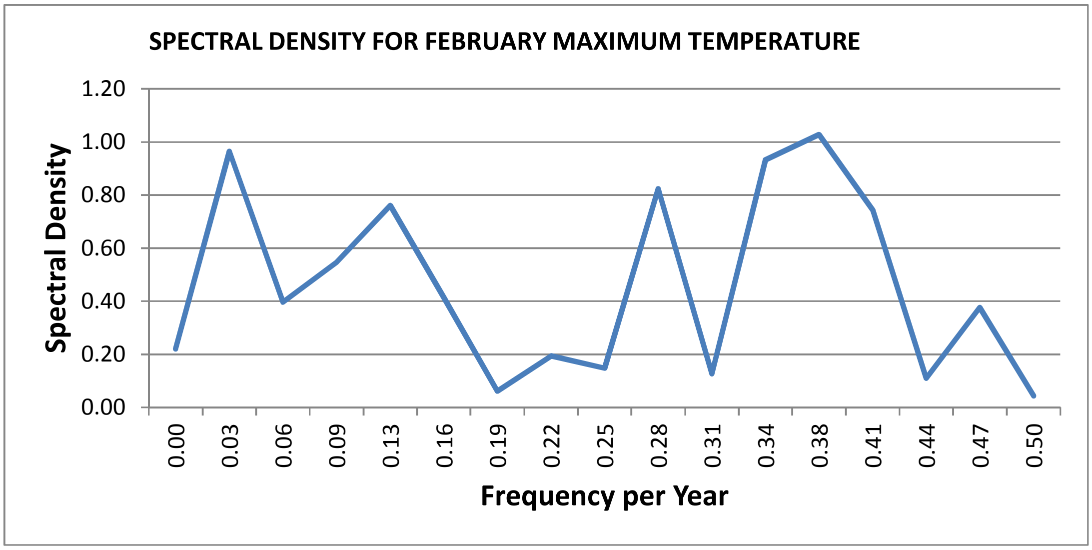


Figure 4.24 spectral density for February maximum temperature over Kitale

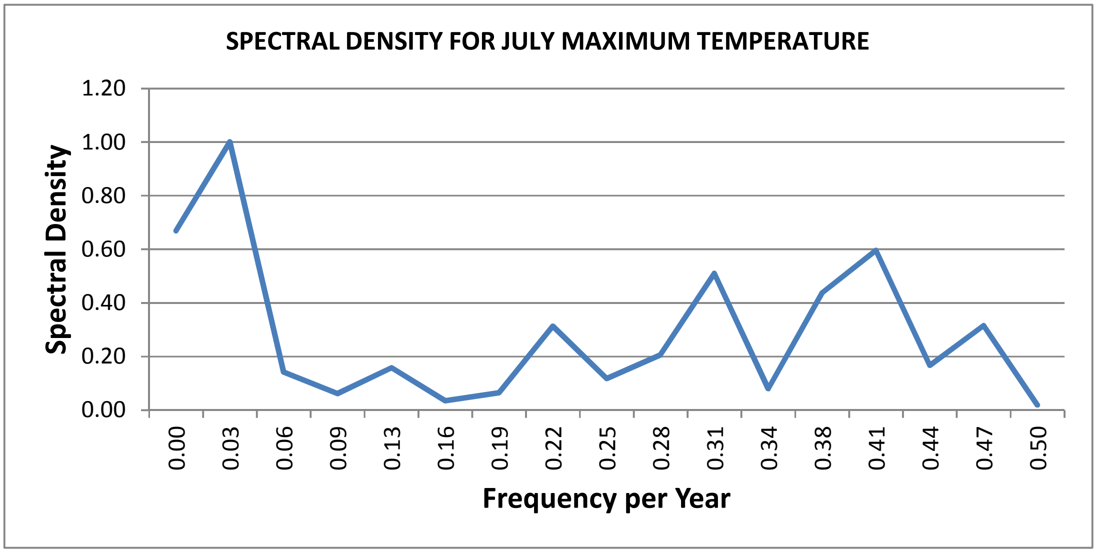


Figure 4.25 spectral density for July maximum temperature over Kitale

4.1.3 Nature of Variability and Change in Minimum Temperature in Uasin Gishu

The mean, standard deviation, skewness, kurtosis coefficient of variability and reliability of minimum temperature at Eldoret during the two sub-periods is shown in table 4.3. The table indicates more shifts in the characteristics of minimal temperatures in the region compared to the maximum as explained in the previous sub-section. For example the coefficient of variability in the second sub-period is higher than the first. This is an indication in the increase in the frequency of occurrence of extreme temperatures. There is a general increase in the mean minimum temperature for all months (figure 4.26) except February to April. From figure 4.26 the month with highest minimum temperature is April and the lowest in September. Higher night temperatures occurring in April are attributed to maximum cloud cover during this month which traps the out- going long wave radiation. On the other hand, in September the nights are very cold due to low cloud cover and hence most of the long wave radiation escapes to the outer space. Positive trend was observed in the annual minimum temperature (figure 4.27). Negative trend observed in the minimum temperature in April (figure 4.28) is consistent with the decrease in cloud cover associated with decrease in rainfall as discusses in section 4.1.1.1 during this month. The positive trend observed in the minimum temperature in September (figure 4.29) on the other may be linked with the increase in cloud cover associated with increase in rainfall also discusses in section 4.1.1.1 during this month.

The results from spectral analysis depicted similar results as the maximum temperature; thus the months with positive trend were dominated with the low frequency cycle as can be seen for the case of September minimum temperature (Figure 4.31). The annual minimum temperature has a positive trend and spectral frequency also show the dominance of low frequency cycle (fig 4.32). In April where the trend was negative the dominant cycles were 16-11years and 3-4 years (fig 4.30).

Table4.5 the temporal variation in the minimum temperature statistics over Eldoret

DATA SET		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUB-SET ONE	MEAN-1	10.01	10.69	11.32	12.02	11.19	10.29	10.01	9.79	9.37	10.53	11.09	10.46
	STD-1	0.71	1.20	0.81	0.65	0.74	1.31	0.93	0.78	1.08	0.84	0.69	0.62
	SKEW-1	0.51	0.52	-0.89	1.48	0.21	1.77	1.71	-0.19	1.61	-0.94	0.17	-0.41
	KURT-1	-0.28	-0.57	1.02	3.44	-0.20	5.89	3.26	-0.30	4.37	0.49	-0.30	-0.23
	CV-1	7.14	11.26	7.14	5.41	6.64	12.75	9.28	7.92	11.51	7.99	6.24	5.88
SUB-SET TWO	MEAN-2	10.49	10.42	11.18	11.64	11.84	10.33	10.23	10.67	9.96	11.26	11.55	11.24
	STD-2	1.29	1.49	1.14	1.30	1.65	1.07	1.73	1.04	1.26	1.07	0.80	1.35
	SKEW-2	0.45	-0.28	-0.49	-0.94	1.58	0.59	-1.22	0.71	0.15	-1.05	-0.06	0.21
	KURT-2	0.51	0.61	0.30	1.10	4.63	-0.90	2.26	0.98	-0.80	2.44	-0.53	-0.88
	CV-2	12.25	14.30	10.20	11.18	13.93	10.36	16.87	9.70	12.66	9.49	6.89	11.99
WHOLE SET	MEAN	10.24	10.56	11.25	11.84	11.51	10.31	10.11	10.22	9.65	10.88	11.32	10.84
	STD	1.04	1.34	0.97	1.02	1.29	1.18	1.36	1.00	1.19	1.01	0.77	1.09
	SKEW	0.82	-0.06	-0.67	-1.02	1.98	1.32	-0.69	0.62	0.75	-0.56	0.15	0.80
	KURT	1.37	0.30	0.61	3.11	7.47	3.33	2.78	1.19	0.22	0.74	-0.52	0.49
	CV	10.20	12.65	8.62	8.63	11.20	11.47	13.41	9.81	12.33	9.30	6.79	10.10

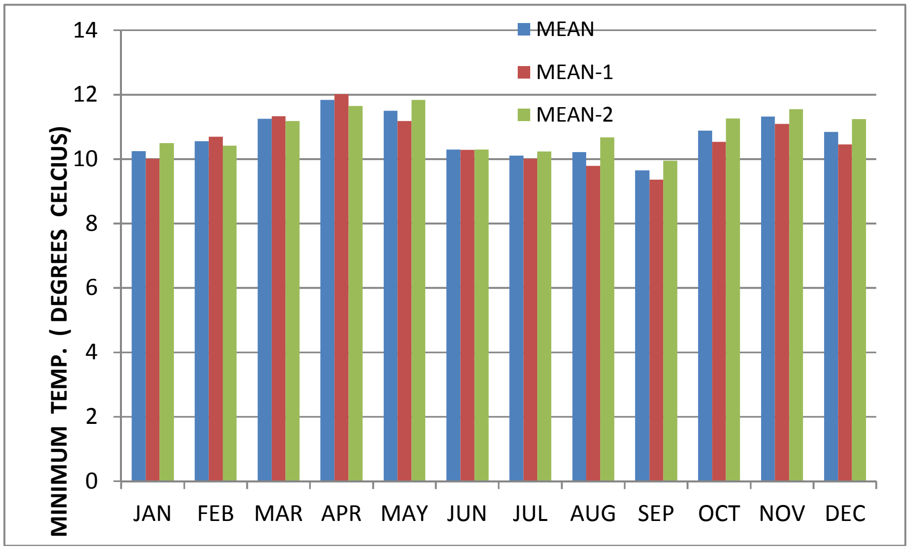
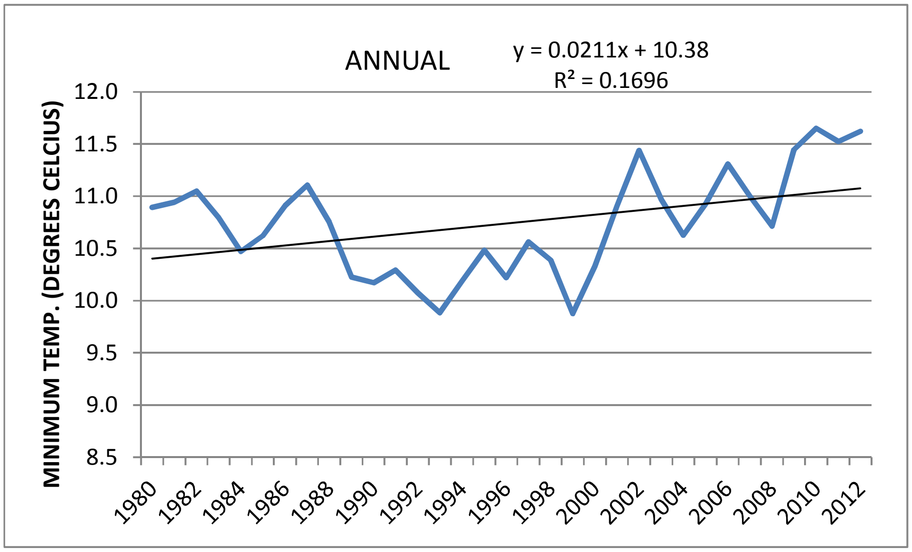


Figure 4.26 Comparison of the mean minimum temperature over the whole period and over the two sub-periods over Eldoret



4.27 The time series of the mean annual minimum temperature at Eldoret

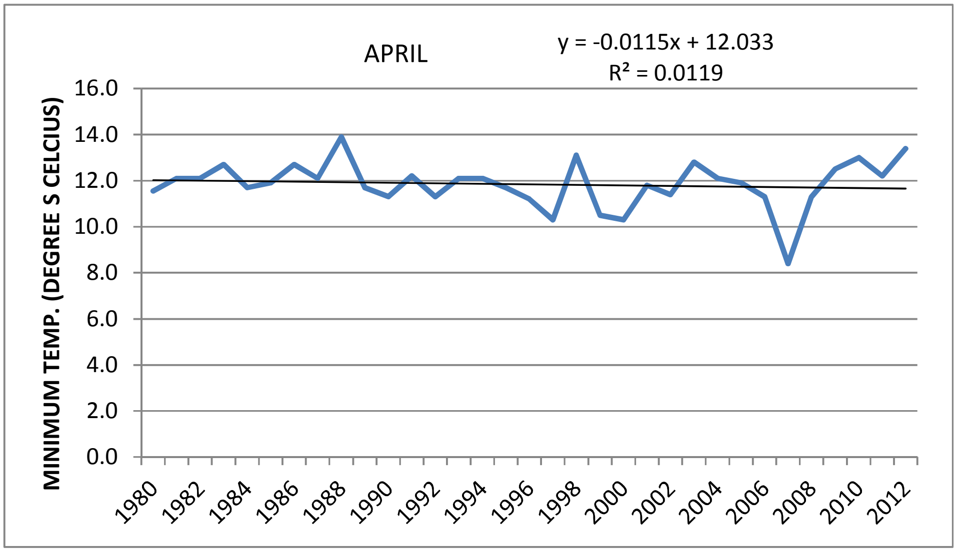


Figure 4.28 Time series of the April minimum temperature at Eldoret

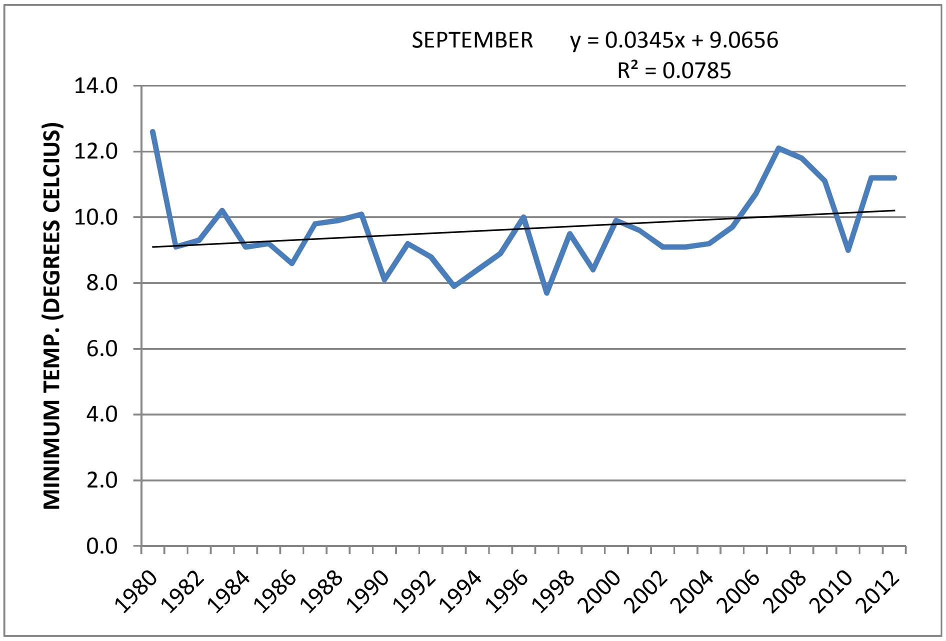


Figure 4.29 Time series of the September minimum temperature at Eldoret

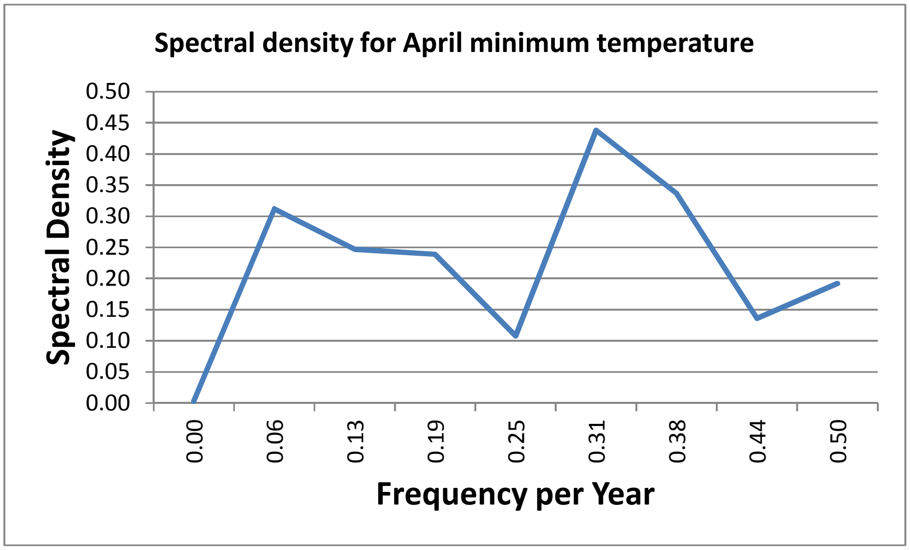


Figure 4.30 Spectral density for April Minimum temperature at Eldoret

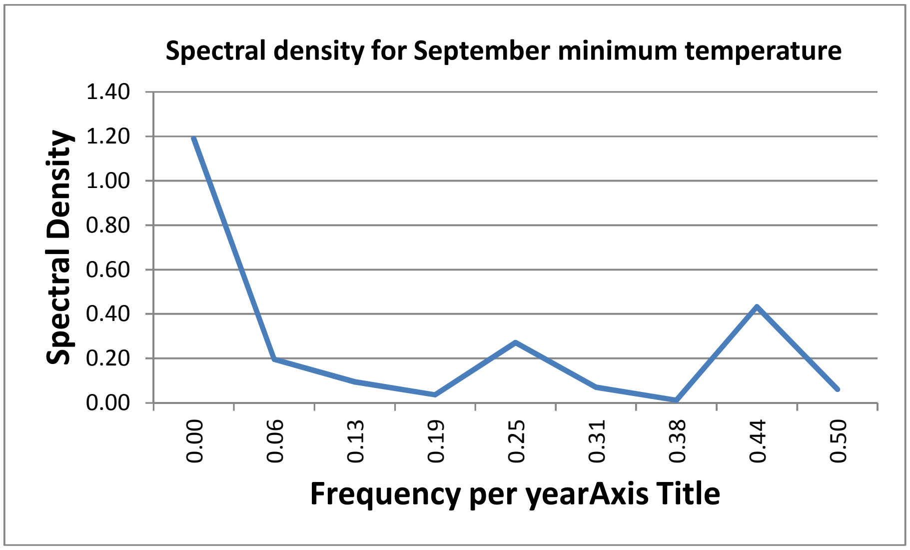


Figure 4.31. Spectral density for September Minimum temperature at Eldoret

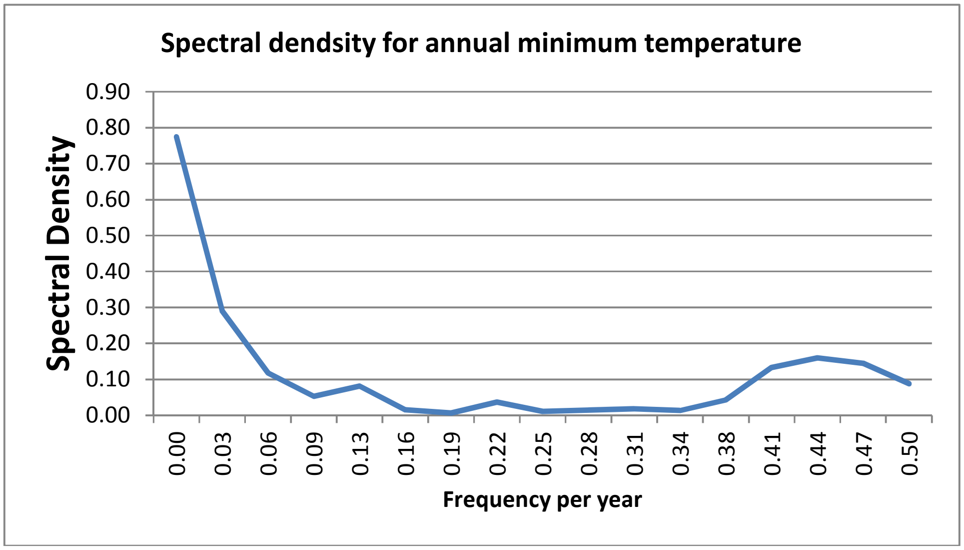


Figure 4.32 Spectral density for Annual Minimum temperature at Eldoret

4.1.6 Nature of Variability and Change in Minimum Temperature in Trans-Nzoia County

The mean, standard deviation, skewness, kurtosis coefficient of variability and reliability of minimum temperature at Kitale during the two sub-periods is shown in table 4.6. From this table it is noted that there is more shift in the characteristics of minimum temperature over the two sub-periods. For example the coefficient of variability in the second sub-period is higher than the first. This indicates an increase in the incidences of extreme temperatures. For figure 4.33, it indicates a general rise in the mean minimum temperature for the months from February to April. It can also be seen from this that the highest minimum temperature occurs in April and the lowest in September. Since the minimum temperature are observed at night, (usually at dawn), high minimum temperature occurring in April may be attributed to maximum cloud cover during this month which trap the outgoing long wave radiation. On the other hand in September, the nights are very cold due to low cloud cover and hence most of the long wave radiation escapes to the outer space. Positive trend was observed in the annual minimum temperature (figure 4.34). Negative trend observed in the minimum temperature in April (figure 4.35) is consistent with the decrease in cloudiness associated with decrease in rainfall as discusses in section 4.1.1.1 during this month. The positive trend observed in the minimum temperature in September (figure 4.36) on the other hand may be linked with the increase in cloudiness associated with increase in rainfall also discusses in section 4.1.1.1 during this month.

The minimum temperature was subjected to spectral analysis. Spectral analyses are shown in figures 4.37 to 4.39. Low frequency variability is evident which is associated with trends. Other dominant peaks included 8, 4.6, 3.2and 2.1 years.

Table 4.6 The temporal variation in the minimum temperature statistics over Kitale

DATA SET		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUB-SET ONE	MEAN 1	10.73	11.42	12.38	13.26	13.06	12.24	11.59	11.47	10.86	11.69	11.72	10.93
	STD-1	0.59	0.73	0.65	0.48	0.51	0.60	0.55	0.63	0.81	0.61	0.80	0.78
	SKEW-1	0.22	0.15	-0.61	-0.17	-0.35	-0.21	-0.58	0.24	-2.29	0.11	0.80	1.14
	KURT-1	-0.35	1.26	0.21	-0.44	-0.73	-1.01	-0.57	0.26	8.05	1.05	-0.52	0.63
	CV-1	5.52	6.35	5.27	3.62	3.93	4.93	4.71	5.49	7.47	5.24	6.79	7.14
SUB-SET ONE	MEAN 2	11.34	11.79	12.86	13.72	13.58	12.57	12.34	12.28	12.18	12.82	12.32	11.49
	STD	0.94	0.82	0.82	0.55	0.60	0.82	0.64	0.42	0.84	0.71	0.49	0.80
	SKEW	-0.43	-0.10	1.46	0.35	-0.78	-0.91	-0.26	-0.43	1.29	0.24	0.73	-0.64
	KURT	-0.38	-0.07	4.45	-1.29	0.12	1.88	-0.27	-0.14	3.35	1.28	0.21	1.06
	CV	8.31	6.97	6.36	3.98	4.43	6.55	5.16	3.38	6.89	5.54	3.94	6.94
WHOLE SET	MEAN	11.03	11.60	12.61	13.48	13.31	12.40	11.95	11.87	11.50	12.24	12.01	11.20
	STD	0.83	0.78	0.77	0.56	0.61	0.73	0.69	0.67	1.05	0.87	0.72	0.83
	SKEW	0.20	0.09	0.81	0.24	-0.25	-0.43	-0.03	-0.41	-0.15	0.26	0.11	0.22
	KURT	-0.49	0.13	3.65	-0.27	-0.66	0.54	-0.22	-0.43	3.55	0.12	-0.76	-0.63
	CV	7.52	6.76	6.08	4.14	4.59	5.86	5.80	5.64	9.17	7.09	6.02	7.38

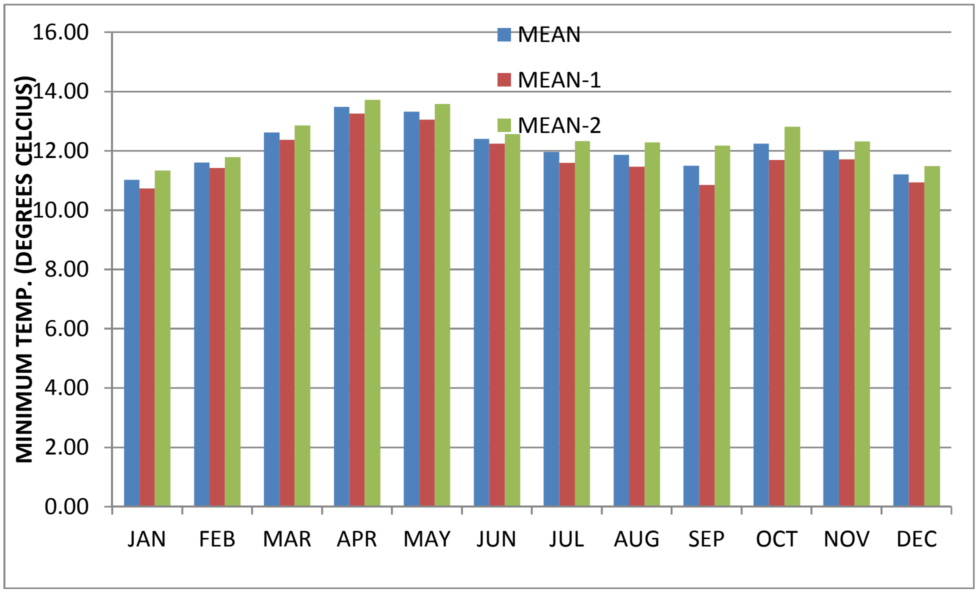


Figure 4.33 Comparison of the mean minimum temperature over the whole period and over the two sub-periods over Kitale

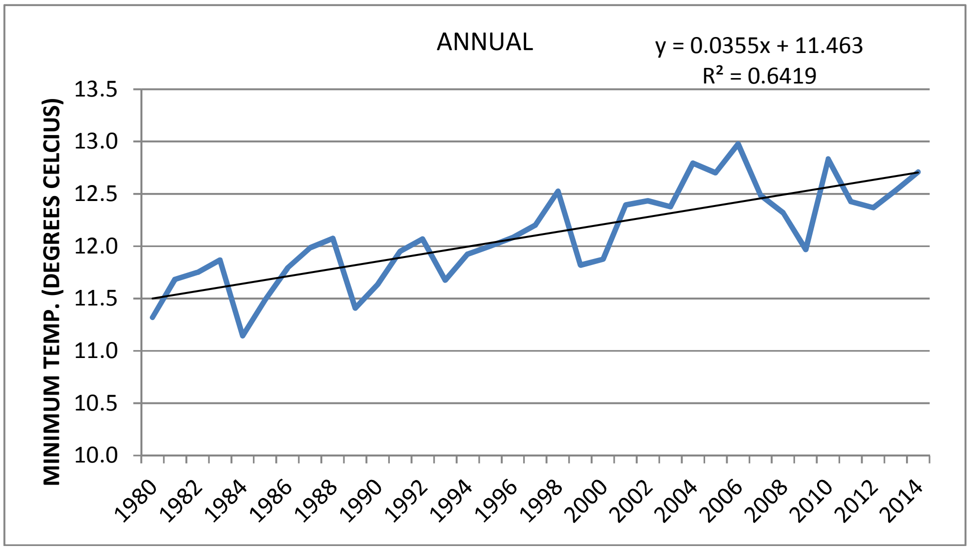


Figure 4.34thetime series of the mean annual minimum temperature at Kitale

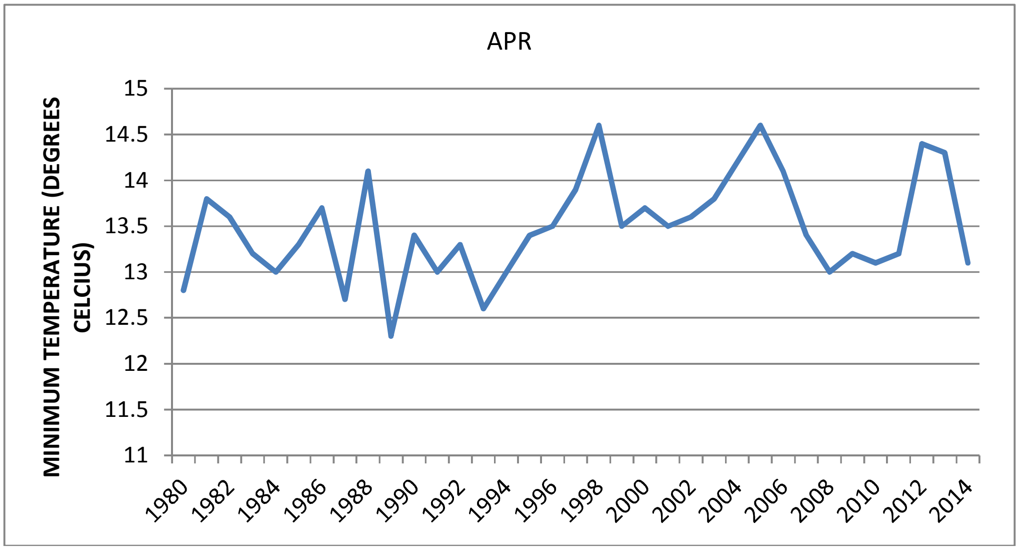


Figure 4.35 Time series of the April minimum temperature at Kitale

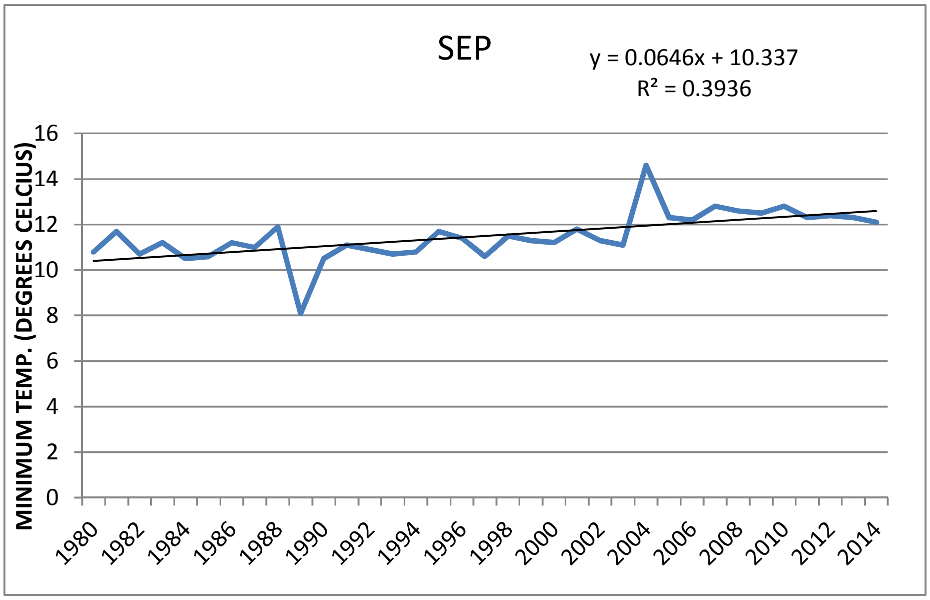


Figure 4.36 Time series of the September minimum temperature at Kitale

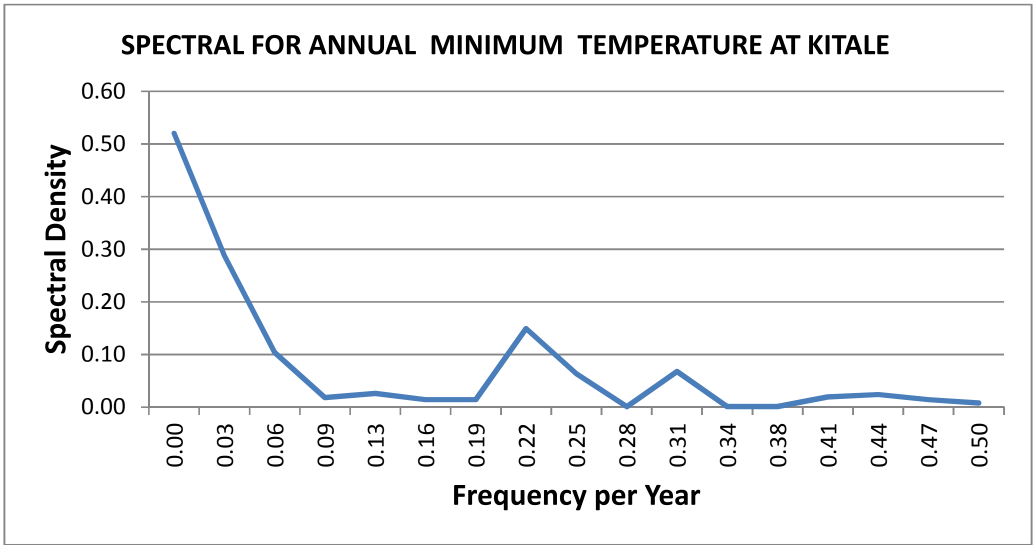


Figure 4.37 spectral density for the annual minimum temperature at Kitale

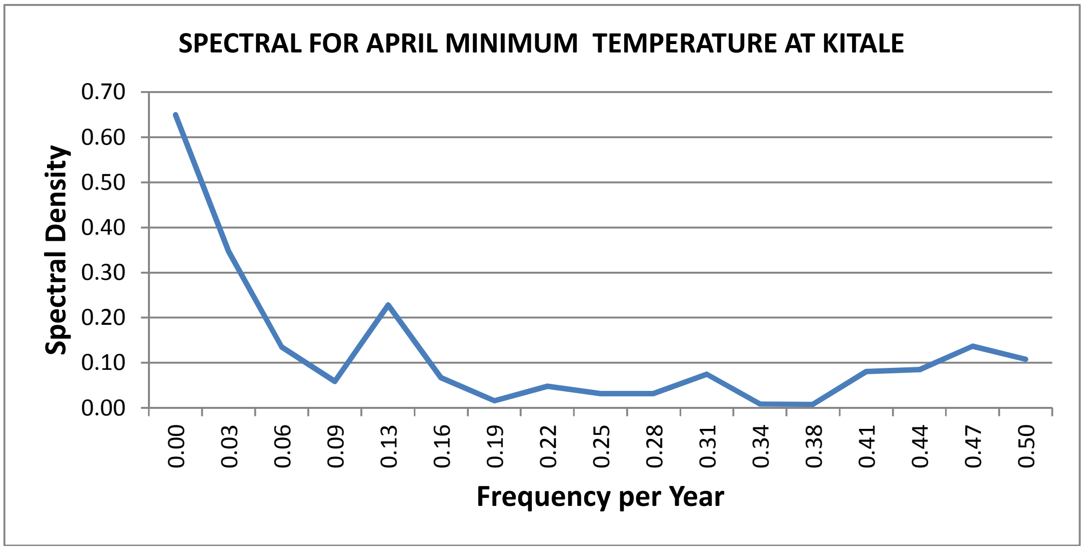


Figure 4.38 spectral density for April minimum temperature at kitale

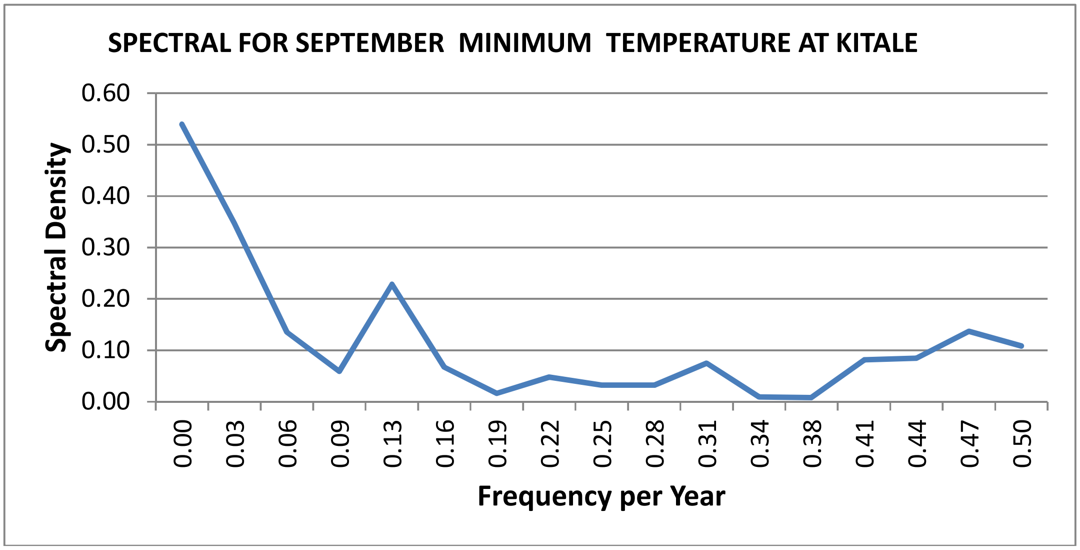


Figure 4.39 spectral density for the month of September over Kitale.

4.2 Results on the Linkage between Climatic Variability and Maize Yield

Table 4.7 shows the correlation between the weather parameters and maize yield in the two counties. In the Uasin GishuCounty, positive significant correlation values were observed between the maize yield and July and September rainfall. However, the month of September in both counties was noted to have a high correlation of yield and rainfall of 0.653 and 0.624 for Trans-Nzoia and Uasin Gishu respectively which was significant. The correlation between maximum temperature and yield was relatively high in May (0.126) and July (0.100) in Trans-Nzoia while May (0.274) and July (0.187) in Uasin Gishu County. However these correlations were not significant. For minimum temperatures, the correlation with yield was relatively high between June (0.339), July (0.204) and August (0.198) in Trans-Nzoia which was also not significant. Correlation between minimum temperatures and yield was relatively high between July (0.569) and August (0.514) in Uasin Gishu which was significant.

The rainfall for other months during the growing season did not show significant correlation, as demonstrated later in this section, rainfall was observed to have nonlinear relationship with the yield. Negative significant correlation was observed between the maximum temperature during , March and September. High maximum temperature during January and March increase evaporation of soil moisture while during September high temperature hasten the drying of the maize before they are fully mature hence decreasing their weight. Minimum temperature has significant positive correlation during July and September. The extreme low minimum temperature leads to frost which damage plant cells.

Similar results were observed in the Trans-Nzoia County though the correlation values were generally lower compared to Uasin-Gishu.

Figure 4.40 to 4.42 show the scatter diagram for yield and rainfall during March, April and May respectively for the Uasin-Gishu while figure 4.43to 4.45 show for the case of Trans-Nzoia. It can be seen that for all the three months during the March to May rainfall season there is a nonlinear relationship between rainfall and yield. Thus initially yield increases with rainfall up to an optimum value and thereafter it decrease with increase in rainfall. In Uasin-Gishu (Trans-Nzoia) the optimum rainfall for March, April and May were 86mm (90mm), 113mm (181mm), and 187mm (200mm) respectively.

Figure 4.46 and 4.47 show the simulated verses the observed yield in Uasin-Gishu and Trans-Nzoia respectively. In Uasin-Gishu the linear regression model explained 57% of the relationship between the simulated and observed yield while in Trans-Nzoia the linear regression model explained 54% of the relationship.

Table 4.7 Correlation between weather parameters and maize yield

TRANSNZOIA		UASINGISHU	
RJAN	-0.130	RJAN	0.096
RFEB	0.122	RFEB	0.614
RMAR	0.017	RMAR	0.018
RAPR	0.079	RAPR	-0.130
RMAY	-0.040	RMAY	0.223
RJUN	-0.096	RJUN	0.196
RJUL	0.140	RJUL	0.308
RAUG	0.094	RAUG	0.268
RSEP	0.653	RSEP	0.624
ROCT	-0.050	ROCT	-0.133
RNOV	0.046	RNOV	-0.164
RDEC	-0.107	RDEC	0.042
TXJAN	0.268	TXJAN	-0.403
TXFEB	-0.039	TXFEB	0.048
TXMAR	-0.212	TXMAR	-0.375
TXAPR	0.115	TXAPR	-0.140
TXMAY	0.126	TXMAY	0.274
TXJUN	-0.057	TXJUN	0.092
TXJUL	0.100	TXJUL	0.187
TXAUG	0.006	TXAUG	-0.106
TXSEP	-0.363	TXSEP	-0.652
TXOCT	-0.114	TXOCT	-0.147
TXNOV	0.158	TXNOV	0.017
TXDEC	-0.009	TXDEC	0.057
TMJAN	-0.047	TMJAN	0.123
TMFEB	0.269	TMFEB	0.407
TMMAR	-0.090	TMMAR	0.275
TMAPR	-0.111	TMAPR	0.112
TMMAY	0.124	TMMAY	0.044
TMJUN	0.339	TMJUN	0.200
TMJUL	0.204	TMJUL	0.569
TMAUG	0.198	TMAUG	0.514
TMSEP	0.065	TMSEP	0.457
TMOCT	-0.011	TMOCT	0.373
TMNOV	-0.076	TMNOV	0.293
TMDEC	-0.071	TMDEC	0.093

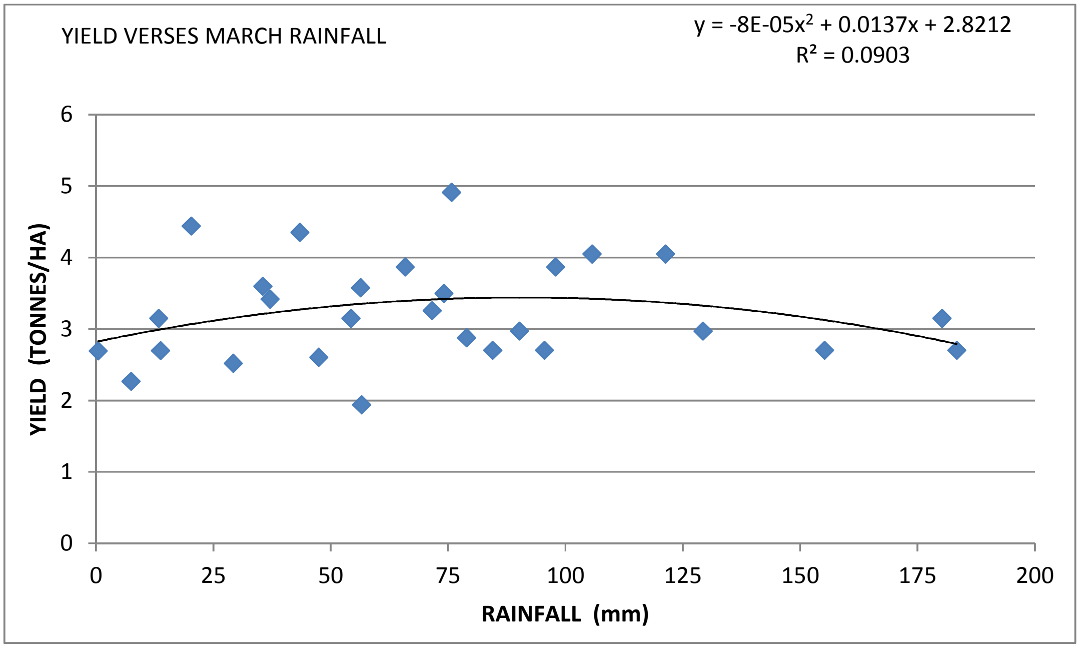


Figure 4.40 Scatter diagram showing the relationship between maize yield in Uasin Gishu County and March rainfall

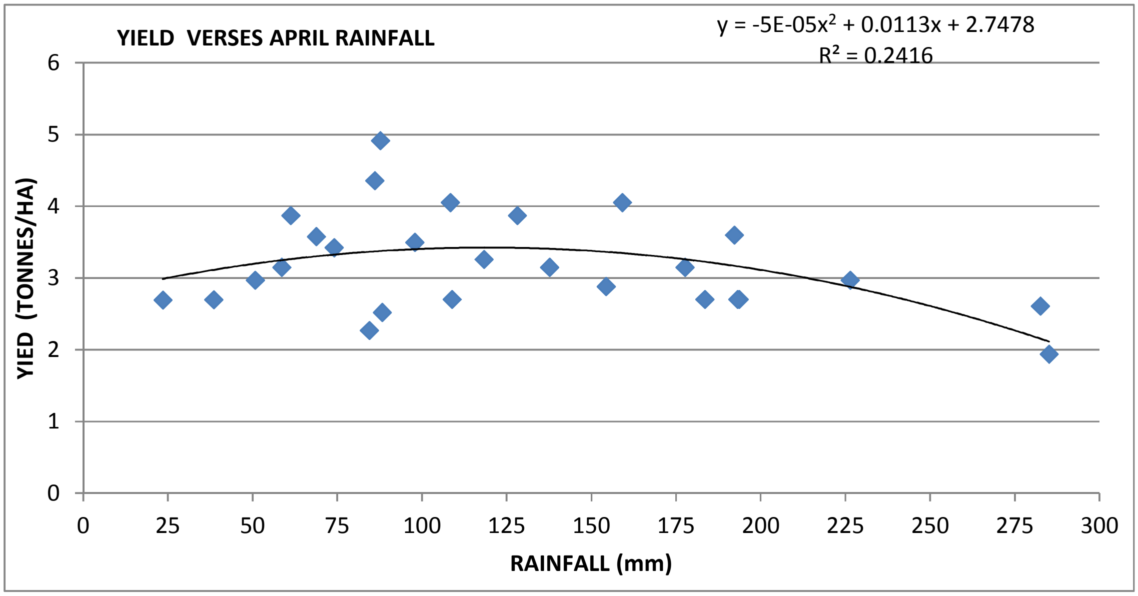


Figure 4.41 Scatter diagram showing the relationship between maize yield in Uasin Gishu County and April rainfall

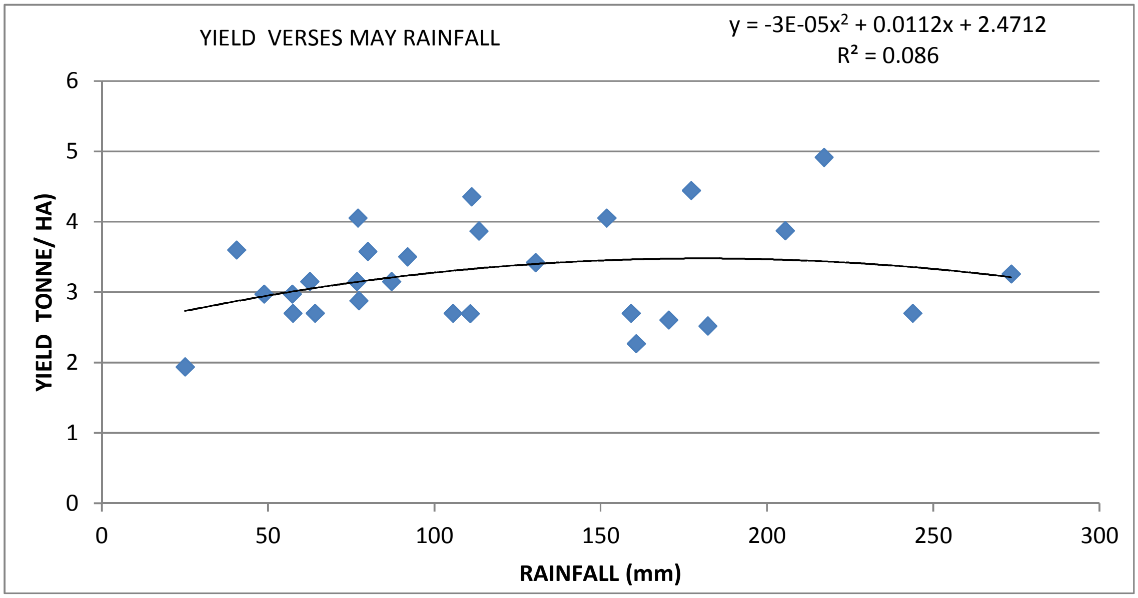


Figure 4.42 Scatter diagram showing the relationship between maize yield in Uasin-Gishu County and May rainfall

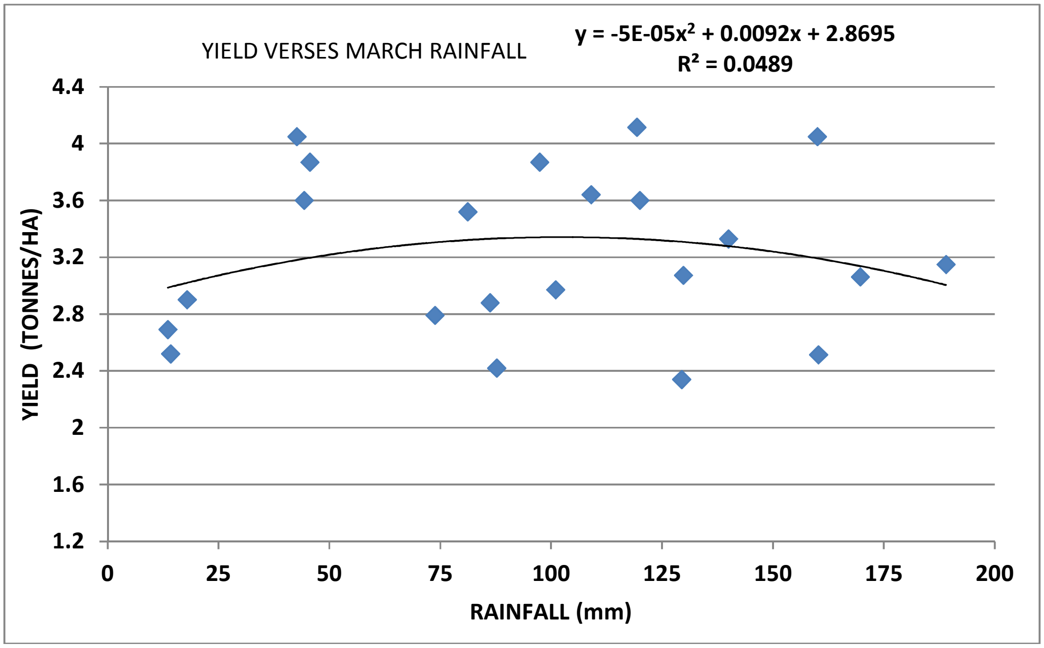


Figure 4.43 Scatter diagram showing the relationship between maize yield in Trans-Nzoia and March rainfall.

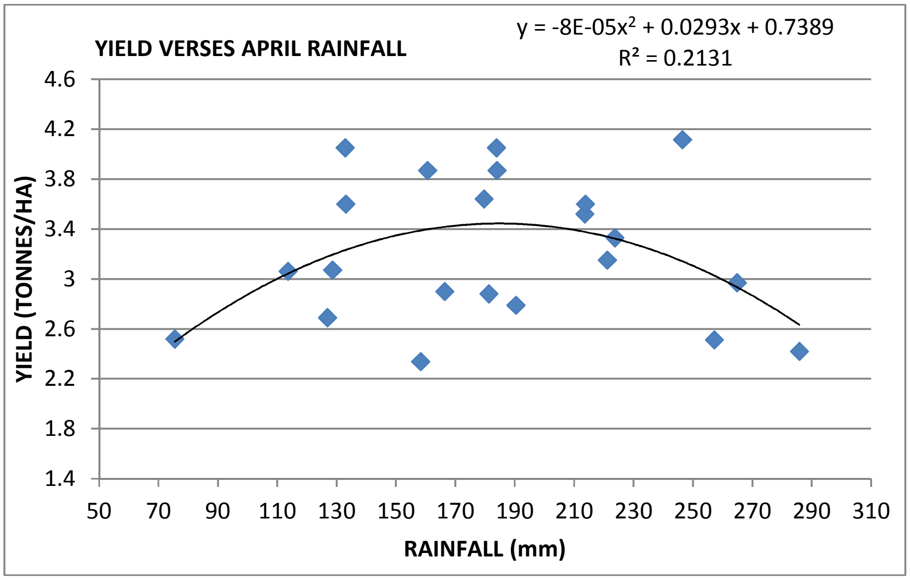


Figure 4.44 Scatter diagram showing the relationship between maize yield in Trans-Nzoia and April rainfall

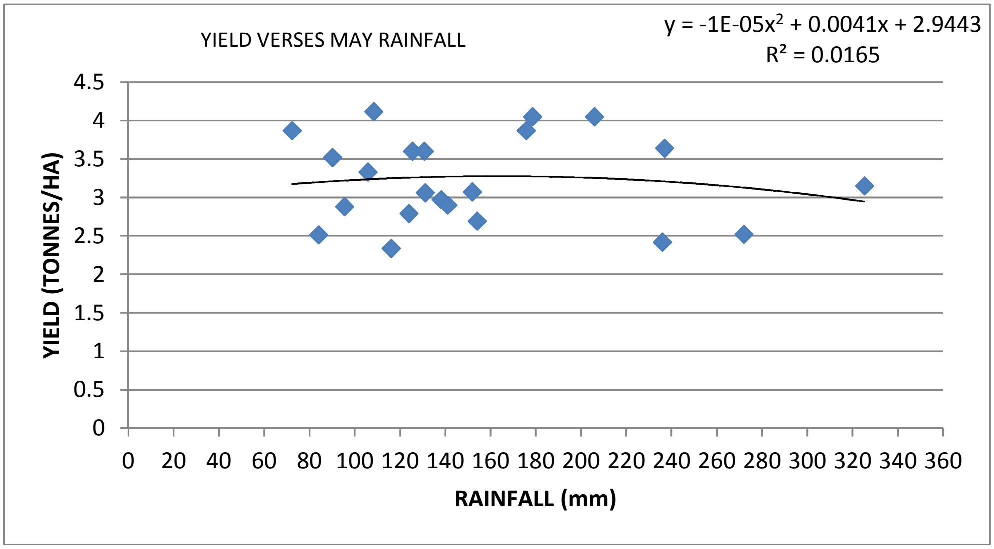


Figure 4.45 Scatter diagram showing the relationship between maize yield in Trans-Nzoia and May rainfall

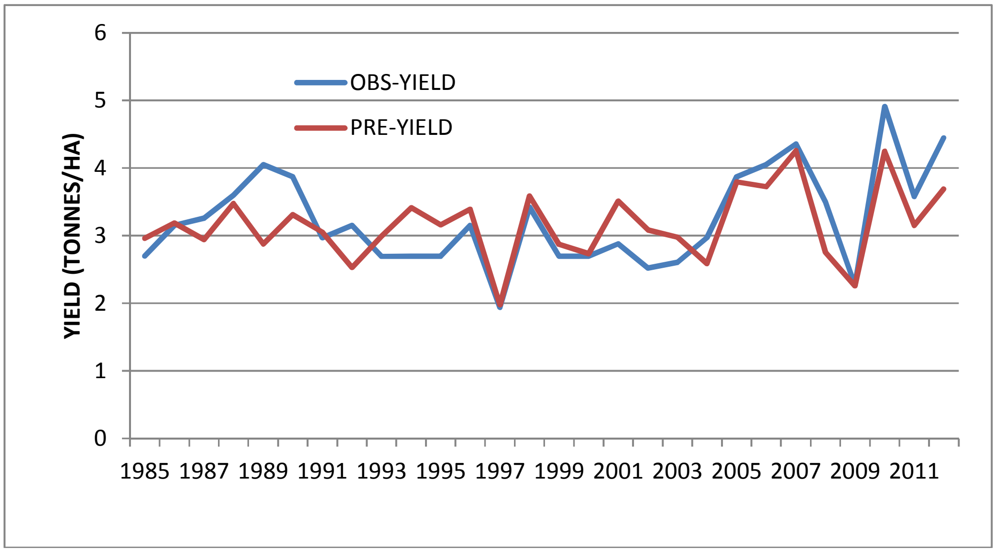


Figure 4.46The observed and simulated yield in Uasin-Ngishu

(Regression equation Y= 8.902-0.347*TXMAR+0.014*TMJUN+0.247*TMJUL+0.004RJUN

(Squared multiple R: 0.565))

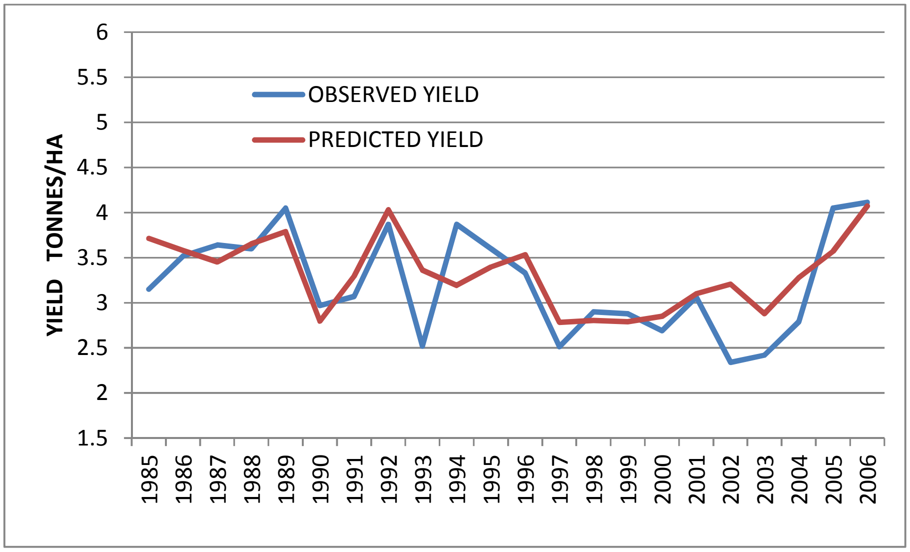


Figure 4.47 The observed and predicted yield for Trans-Nzoia

(*PREDICTED YIELD =17.1419-0.012*RJUN-0.006*RAUG-0.711*TXMAY-0.283*TXSEP+0.409*TMJUN+0.616*TMAUG)*

(RJUN, June rainfall; RAUG, August rainfall; TXMAY, May maximum temperature; TXSEP, September maximum temperature; TMJUN, June minimum temperature; TMAUG, August minimum temperature) $R^2 = 0.54$

4.3. Results from analysis of questionnaires

Out of the 223 questionnaires that were issued to the farmers, 220 were completed and submitted back. It yielded a 98.7% response rating which was considered reliable to draw conclusions. This part of the study sought to establish the challenges maize farmers face due to climatic change in Uasin-Gishu.

4.3.1 Demographic Characteristics

The study sought to identify the demographic characteristics of the respondents. These characteristics were significant in discussing the findings of the study.

4.3.1.1 Gender of Respondents

The majority (82.7%; 182) of the respondents were male while only 17.3% (38) were female. This implied that males as opposed to females were engaged in large scale maize farming. This may be explained by among other factors by land ownership which is mainly dominated by male and the fact that men are the head of majority of the homes surveyed.

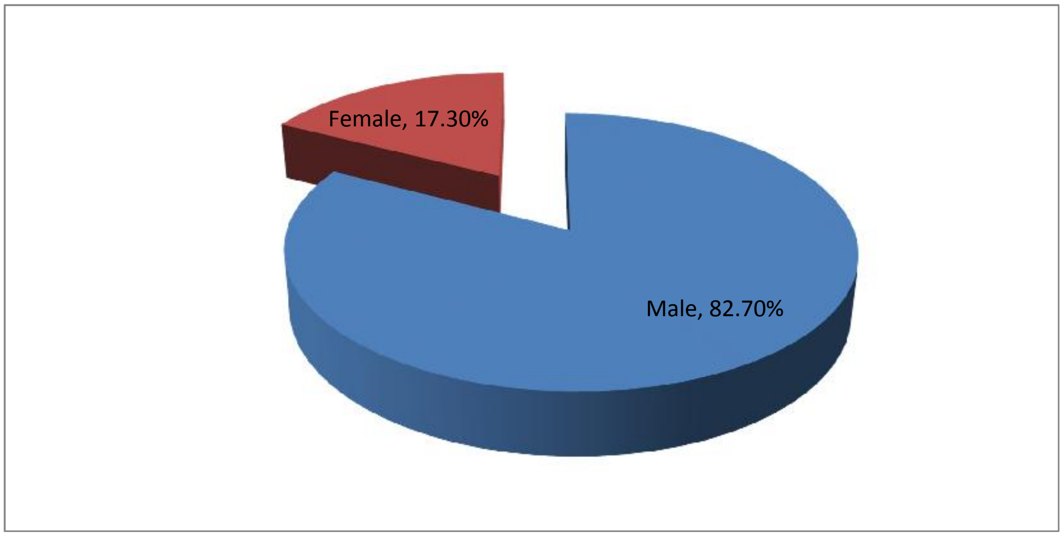


Figure 4.48: Distribution of respondents by gender

4.3.1.2 Age of Respondents

Of the sampled respondents, 39.5% (87) were aged between 41 and 50, 31.4% (69) were aged between 31 and 40, 24.1% (53) were aged over 51 while the minorities (5%; 11) were aged between 18 and 30. The reasons why majority of the respondents were aged above 31 years was; majority of farmers found in this age group own farms and hence are able to practice maize farming.

Table 4.8: Distribution of respondents by age

Age of respondents (years)	Frequency	Percentage
18-30	11	5.0
31-40	69	31.4
41-50	87	39.5
>51	53	24.1
Total	**220**	**100.0**

4.3.1.3 Length of time in Maize farming Practice

The study also sought to establish the length of time that respondents had been in maize farming practice. Thus helped to inform the researcher on the authenticity of the responses obtained with reference to climate change elements, given that changes in climate is experienced after a fairly long duration of time. The majority (52.7%; 116) of the respondents had been practicing maize farming for over 10 years, 45% (99) for between 5 and 10 years while the minority; 1.4% and 0.9% respectively for between 2 and 5 years and less than 2 years respectively.

Table 4.9: Distribution of respondents by length of time in maize farming practice

Length of maize farming practice (years)	Frequency	Percentage
< 2	2	0.9
2-5	3	1.4
5-10	99	45.0
>10	116	52.7
Total	**220**	**100.0**

4.3.1.4 Size of Land on which Maize farming is practiced

The size of land on which respondents practice maize farming, was also established. Majority of the respondents (51.4%) were practicing maize farming on land between 26 and 50 acres, 42.3% (93) on land between 51 and 100 acres, 5.5% (12) on land that was over 100 acres while only 0.9% (2) were practicing maize farming on land less than 25 acres. This pattern was attributed to the fact that respondents were drawn from large scale maize farmers who ordinarily commit large tracts of land to maize farming.

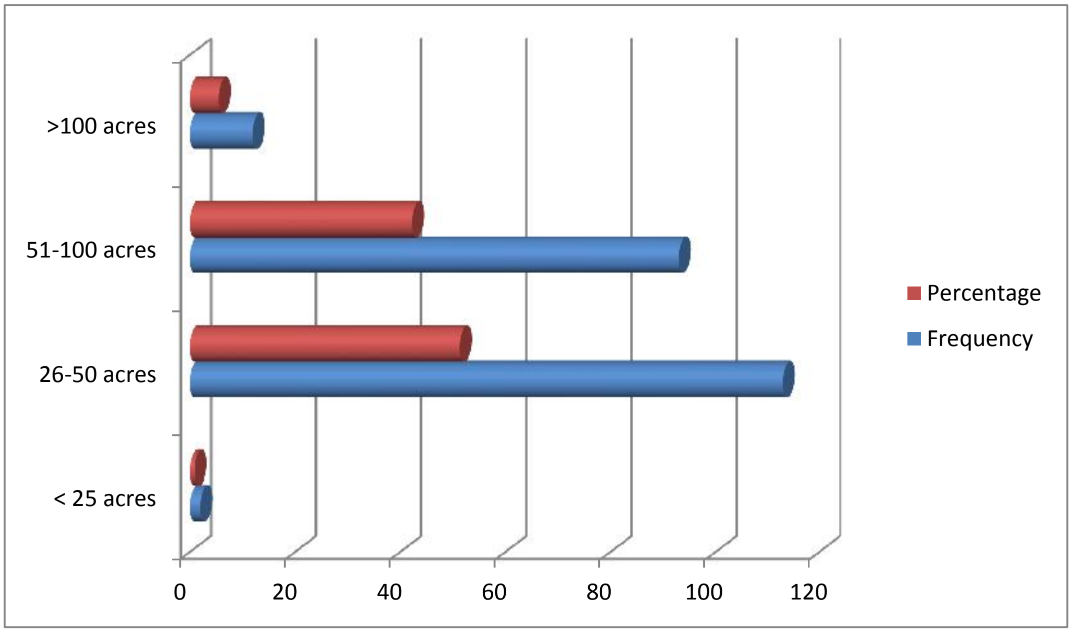


Figure 4.49: Size of Land on which Maize farming is practiced

4.3.2 Challenges Maize Farmers face due to Climate Change

Respondents were asked to indicate the challenges that they face that have been occasioned by variability in precipitation amounts and temperature. The majority (196; 89.1%) observed that climate variability posed serious effects on phenology (maize sowing, flowering and grain filling) indicating that this resulted in poor timing for planting and harvesting times. A proportion of 46.8% (103) of the respondents indicated that they experienced poor yields of the maize crop due to unfavorable rainfall amounts and variations in temperature. A further 45% (99) indicated that the variability in rainfall amounts and temperature have led to uncertainty in yield production which affects general farmers' planning calendar.

A proportion of 37.3% (82) of the respondents indicated that the climate change had led to poor quality maize harvest while 35.9% (79) of the respondents indicated that the variability in rainfall amounts and temperature ranges had led to increased infestation of the maize crop by pests and tropical illnesses. Figure 4.38 illustrates this finding.

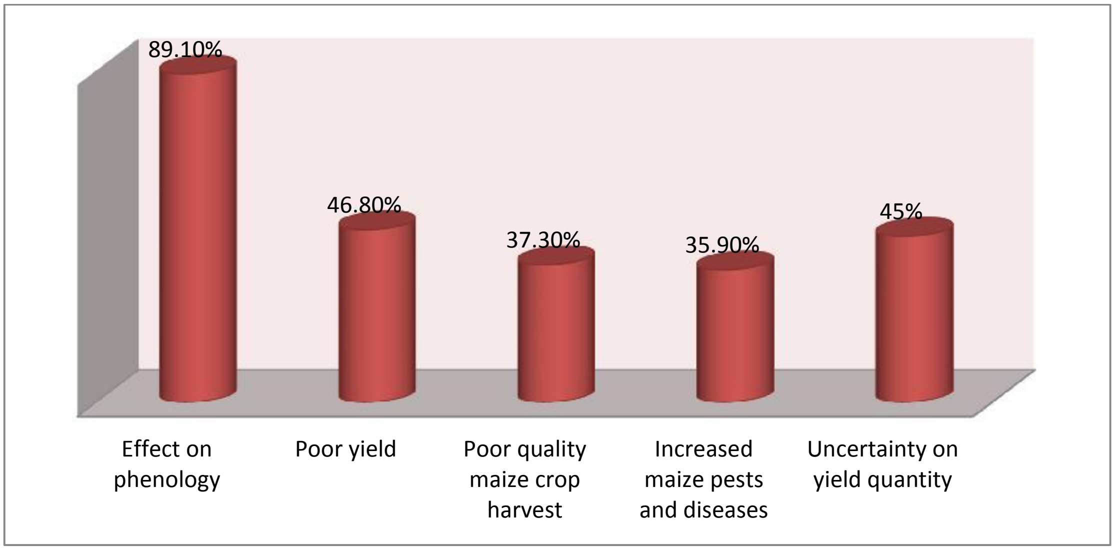


Figure 4.50: Challenges farmers face due to climate change

Hope (2009) concurs with these findings by indicating that the agricultural activity in Africa is affected by climate variation.

4.4 The results on Economic Impact of Climate Change on Maize Production

The results that were obtained using the Ricardian Approach to investigate the impact of climate change on maize production in in Uasin-Gishu county is presented in this section.

The relationship between climate variables and net farm revenue per hectare was investigated using elasticity analysis. Elasticities are calculated at the mean so as to assess the relative change in net farm revenue per hectare associated with a unit change in temperature and precipitation According to the results presented in Table 4.10, increasing temperatures between March and May from the current levels would reduce net farm revenue by 43% while increasing precipitation between March and

May from the current levels would increase net farm revenue by 13%. An increase in precipitation from the current levels between June and August would reduce net farm revenue by 12%. The results also indicate that net farm revenue is more sensitive to changes in temperature than changes in precipitation.

Table 4.10: Estimates of elasticities to climatic factors

Significant change months	**Temperature**	**Precipitation**
March-May	-0.43	0.13
June-August		-0.12

The outcome shows that there exists a significant non-linear relation between climate variables and net farm revenue per hectare as shown in Table 4.11. As indicated by the results, high temperatures between March and May have an adverse effect on net farm revenue. This may be due to adverse effects of temperatures during the formative growth of the maize crop (formative growth of the maize plant takes place between March and May).

The results also indicate that the average temperature between March and May has an inverted U shaped relationship with net maize revenue per hectare. The positive squared term for March-May average temperature indicates that there is a minimum level of temperature during that period required for maize production and that more or less temperature during that period will increase net farm revenue per hectare. The results also point out that high precipitation between March and May has a positive impact on net farm revenue while high precipitation between June and August has a negative impact. High precipitation during the months of March to May would have a positive impact on the formative growth of the maize crop while high precipitation between the months of June to August would disrupt the maturing and harvesting of the maize plant (Kabubo- Mariara and Karanja, 2007).

According to the results, the precipitation between June and August has an inverted U shaped relationship with net maize revenue per hectare while the average precipitation between March and May has a "U" shaped relationship with the same. The positive squared term for average precipitation between June and August indicates that there is a minimum level of precipitation during that period required for maize production and that more or less precipitation during that period will increase net farm revenue per hectare. The negative coefficient for squared term of the March-May average precipitation indicates optimal level of precipitation between March and May from which the net farm revenue per hectare will decrease if it increases or decreases (Mendelsohn, et al., 1994). The findings with regard to precipitation and temperature agree with those in Kabubo-Mariara and Karanja (2007) and Deressa (2007) who found out that high temperature during the formative period of crops has a negative impact on net farm revenue per hectare while high precipitation has a positive impact.

Table 4.11: Estimated results per net farm revenue per acre

VARIABLES	**MODEL ONE**	**MODEL TWO**	**MODEL THREE**
Constant	4.37	4.52	4.12

March-May temperature	-0.12 *(0.000)	-0.12 *(0.000)	-0.11.* (0.000)
March-May temperature squared	0.011 *(0.001)	0.008.* (0.019)	0.008 * (0.032)
March-May Precipitation	0.003 (0.383)	0.004.(0.264)	0.005 * (0.166)
March-May precipitation squared	-0.0003 *(0.002)	-0.0003 *(0.000)	-0.0004*(0.000)
June-August precipitation	-0.005 *(0.040)	-0.006.*(0.050)	-0.007* (0.004)
June-August precipitation squared	0.0001145*(0.000)	0.0000989.*(0.002)	0.0000916 *(0.003)

* Significant at 5%,

( ) parenthesis represents the P values

CHAPTER FIVE

5.0 CONCLUSIONS, RECOMMENDATIONS AND SUGGESTION FOR FURTHER STUDY

The conclusions and the recommendations drawn from the present study are presented in section 5.1 and 5.2 respectively, while the areas for further study are described in section 5.3

5.1 Conclusion

The study showed that the rainfall during the March to May (long rains) season over both counties has decreasing trend while the October to December (short rains) and July and August rainfall showed positive trend. Besides showing trends, the rains were noted to have become more variable in the recent years. For instance the months of January and February which are supposed to be dry were observed to be wet in some years. This is the time for farm preparation and when rainfall occurs it disrupts this activity.

Both the maximum and minimum temperature over both counties showed increasing trend for all the months. Just like for the case of rainfall increased variability become evidence in the maximum and minimum temperatures was an indicator of increasing seasons of extreme high and low temperature. The periodicities exhibited by the atmospheric and oceanic phenomena such as the El-Nino Southern Oscillation and Quasi-Biennial Oscillation were also depicted by the rainfall and temperature.

The correlation between rainfall and yields during the growing season were generally low due to the fact that the relationship is not linear. Extreme high and low rainfall has a negative effect on maize yield. Similar pattern was observed in the relationship between temperature and maize yield. This is an indication that the highest yield is achieved when there is optimum climatic condition. The linear multiple regression model explained a variance of 57% in Uasin-Ngishu county and 54% in Trans-Nzoia Large scale farmers identified climate variability as a key determinant to maize production. The study revealed gender disparity in the large scale farmer. Thus over 80% large scale farmer were male. Most of those engaged in large scale farming were over 40 years, meaning that fewer youth are not involved in large scale maize farming.

The study showed that the effect on of change in climatic element depend on the season, for example, increasing temperatures between March and May from the current levels would reduce net farm revenue by 43% while increasing precipitation between March and May from the current levels would increase net farm revenue by 13%. An increase in precipitation from the current levels between June and August would reduce net farm revenue by 12%. The results also indicate that net farm revenue is more responsive to variation in temperature than changes in precipitation. This is due to the fact that a change per unit temperature has a much far reaching effect than a unit change in precipitation.

5.2 Recommendations

The findings indicate that changes in climate will affect in a number of way maize production in the study areas and hence a negative impact on maize production. Hence there is need to address challenges of climate change on maize production through policy efforts.

Among other policy efforts is creating awareness among maize farmers on climate change. This is vital since climate change has lead to the shift in the rainfall season and there is increased rainfall variability. Thus there is need for adjustment in the maize growing calendar.

Climate change being a reality, there is need for farmers to adopt water conservation strategies that they may apply during rainfall deficiency years.

Irrigation is another policy option that could be considered to mitigate the impact of climate change. Maize production is largely dependent on rainfall and a paradigm shift from rain fed to irrigation based maize production may not only increase production but make it resilient to climate change. Effective dissemination of climate related information to maize farmers should be urgently undertaken. Farmers should be informed on climate change and its likely impacts on maize production. This requires that government sets up effective extension service programs in all the counties in the country. Finally ,there is need for more young people to be involved in large scale farming due to the aging of the sizeable number of large scale farmers.

5.3 Further Research

Additional survey needs to be carried out to include information on farmers' other economic activities and adaptive capacity that would have facilitated the analysis and modeling of the impacts of climate change on maize production in Kenya with and without adaptations and compare the difference. The study recommends that future studies on impact of climate change on agriculture should take into consideration farmers' perceptions of climate change and the adaptation measures of farmers.

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APPENDICES

Appendix 1: Questionnaire for farmers

Kindly tick where appropriate (√).

SECTION A: Background Information

i. Gender

Male ( )

Female ( )

ii. Age ( )

18 – 30 years ( )

31 – 40 years ( )

41 – 50 years ( )

51 years and above ( )

iii. For how long have you been practicing maize farming?

Less than 2 years ( )

Between 2 – 5 years ( )

Between 5 – 10 years ( )

Over 10 years ( )

iv. What is the size of land where you have been practicing maize farming?

Less than 25 ( )

26 – 50 acres ( )

51 – 100 acres ( )

Over 100 acres ( )

v. What is your highest academic qualification?

No formal education Middle school ( )

‘O’ level ‘A’ level ( )

Tertiary level ( )

Technical school University ( )

SECTION B: Climate Change and Maize Production

Kindly answer the following questions to the best of your ability by ticking (√) where appropriate.

1. Rainfall amount and Temperature Ranges

a. Rainfall amounts have been reducing in the past ten years in this region Yes [ ] No [ ]

b. Temperature amounts have been reducing in the past ten years in this region Yes [ ] No [ ]

2. Rainfall amount, temperature ranges and maize production.

a. Maize yield has been increasing in the past ten years in this region. Yes [ ] No [ ]

b. Land under maize farming has been reducing in the past ten years in this region Yes [ ] No [ ]

c. More people are growing maize in this region Yes [ ] No [ ]

iv. Challenges faced by maize farmers occasioned by variability in rainfall amounts and temperature ranges.

In your opinion, what do you think have been the major challenges that you are facing as a result of variations in rainfall amounts and temperature ranges in this region?

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v. Economic Impacts of climate change on Maize production.

Please tick where appropriate.

a. The price of a bag of maize has drastically reduced over the past ten years. True [ ] Not True[ ]

b. the quality of maize harvest has been reducing over the past ten years. True [ ] Not True [ ]

c. The production cost for maize in this region has been increasing over the past ten years. True

[ ] Not True [ ]

d. I am contemplating adopting another crop for farming. True [ ] Not True [ ]

e. There is not enough maize these days to feed my family throughout the year. True [ ]

Not True [ ]