IMPACTS OF DEFORESTATION ON CLIMATE AND IMPLICATIONS ON FOOD PRODUCTION IN SOUTH WEST MAU

BY

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DECLARATION

This Dissertation is my original work and has not been presented to this or any other university.

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CFA, s	Community Forest Association's
FAO	Food Agriculture Organization.
FCC's	Forest Conservation Committee's.
GDP	Gross Domestic Product.
GOK	Government Of Kenya.
GIS	Geographical Information Survey.
IPCC	International Panel On Climate Change.
MFC	Mau Forest Comp
KFWG	Kenya Forest Working Group.
KFS	Kenya Forest Service
KIFCON	Kenya indigenous Forest Conservation
KMD	Kenya Meteorological Department.
MAX	Maximum.
MDG	Millennium Development Goals.
MIN	Minimum.
UNEP	United Nations Development Project.
SDG's	Sustainable Development Goals.
USGS	United Nations Geological Survey.
SPSS	Statistical Packages for Social Science

ABSTRACT

It is increasingly important that forests are very important in sustaining income and rural community livelihoods through food production. It is increasing important for food production assessment in the wake of today's challenge of climate variability and change. More investigations should be done to assess further on impacts of forest cover change in Mau. Food production cannot be produced in an environmentally degraded environment. Improved Food production and security has been a priority in the countries development agenda. The achievement of national food security in Kenya is a major aim of food production. A food secure country improves community livelihoods, creating employment, reduces food insecurity and increases the country's GDP. The Study Objectives are to investigate the impacts of deforestation on climate and implications on food production, assess the trend of forest cover change , analyze the trends of observed rainfall and temperature changes, assess forest cover effects on rainfall and temperature changes, determine relationship between Forest cover change, climate and crop production in the area. Data collection was through satellite images which were analyzed using Landsat images for four climate seasons that is 1988, 1998, 2008 and 2018 and comparative study of forest cover changes. Data on climate change trends was acquired from climate data in the area. For questionnaires and interview schedules, SPSS was used for frequencies and cross tabulation for perceptions and excel and correlation used for analyzing temperature and rainfall data. The research indicated a drastic reduction in size of forest in the south West Block from1988 to present due to deforestation, affecting climate change and thus having implications on food production in the area. It was shown from the observations that there is continued warming since the 1980s to date which has led to reduced food production, hence poor food yields. It was observed that forest cover change drastically occurred in the years due to illegal settlements logging and population increase. The rates of forest cover change due to deforestation have been on the rise. This has impacted on climate change causing climate variability and change of weather seasons which has in turn affected food production in the area. From this study the distribution of precipitation and temperature shows temporal and spatial variations, the results shows that the rainfall amounts have been decreased gradually over the catchment and the temperatures have been significantly increasing, the extremes of drought and floods have affected the crop yields and will continue in the future. Rising temperatures due to climate variability and reduced amount of rainfall have led to depicted trends of reduced food production. Increased temperature coupled with reduced precipitation trends have resulted to reduced food production. Climate variables are positively related to food production; hence food production

over the study area has been negatively affected by these changes as shown by increasing rates of deforestation, from this study the distribution of precipitation and temperature shows temporal and spatial variations.

Key words, Deforestation, climate, Food Production, Observed rainfall and temperature changes, climate variables

CHAPTER ONE

1.0 Introduction.

In this chapter, the general overview, problem statement, guiding questions, hypothesis, Objectives, justification and study area are discussed.

1.1 Background information

Improved Food production is very important for the country's development and its attainment of vision 2030. (Vick, 2012). The achievement of national food security in Kenya is a major key objective of the agricultural sector. The agricultural sector is key in attainment of Vision 2030. It aims to achieve a food secure country which makes a country more developed. The global environmental concerns include variation in climate and its negative effects on sustainable development goals. (SDG's). (FAO, 2007).

Any country that does not produce enough food for its people cannot develop; this has been a crucial part of the global issue concerning development and poverty eradication. Increased temperatures brought about by deforestation affect food production. The agricultural sector is very sensitive to climate change, meaning that agricultural systems are already experiencing negative impacts from the current climate e.g. drought. The sector is one of the economic in Kenya most vulnerable to climate change largely due to the increasing temperatures, changing rainfall patterns and extreme weather events. These patterns are largely driven by regional variability in the future precipitation and geographical exposure to extreme events, particularly drought frequency. (FAO, 2009).

Millions of the world population has been exposed to hunger and drought owing to the rising temperatures. Yields are indications of crop production in terms of quality and quantity Studying on the dimensions of monthly and seasonal temperature and rainfall variations is important as it negatively impacts on ecosystems thus affecting farming. Climate change and Variability lead to decreased crop yields (Lowell *et al*., 2011).

Climate change observed over the last several decades has reduced water availability through various ways. It is closely linked to changes in hydrological cycles, climatic indicators such as floods, temperature, rainfall, increasing rate of evaporation. Unpredictable weather patterns in sub Saharan Africa will push the already poor population depending on agriculture to deeper poverty and vulnerability by the year 2050 according to (IPCC, 2012).

Agriculture is a major source of income to Kenyans through employment and GDP (Gross domestic Product) growth of a country. Food production is one of the most important human requirement, a principal sign and indicator of a healthy and physical wellbeing for good human existence (FAO, 1991)

Rainfall deficiency in the country is a main environmental factor behind insufficient food production. In Kenya particularly, agriculture sector is the main source of livelihoods and a major contributor to the economy, and of utmost importance as regards Self Employment and Kenyan GDP. Improved food production is important for alleviation of hunger. The effect of deforestation on climate, its implications on farming will be investigated by assessing deforestation as a cause to climate change, soil fertility depletion, effects on hydrological cycle. Increased population has led to dramatic changes in forest cover change substantially impacting on yields of crops that are highly susceptible, resulting in poor harvests and hunger. Deforestation degrades natural resources, speeds climate change, and affects hydrological cycle affecting food productivity. Kenyan agriculture is heavily depended on rains. Water availability, soil nutrients and optimal temperature are important for optimal crop production and growth. (FAO, 2002).

According to UNEP, Mau forest lost over 107,000 hectares between 1991 and 2011 of its cover caused by expansion in cultivation, tree poaching and rapid population expansion (KFWG, 2006). Mau Forest Complex (MFC) water tower, together with other water towers has been invaded by human settlement, agriculture, logging, and charcoal production (Rwigi 2014). Over 27% of MFC has been excised and encroached of the over the last two decades. Food production and community livelihoods have been impacted negatively by increased frequency of drought and floods due to increased Carbon dioxide emissions (UNEP 2009).Rainfall is unpredictable and temperatures increase is indicators of climate change. Droughts are more frequent and last longer. Variability in climate decreases crop yields (Lobell *et al*., 2007).

Unpredictable weather conditions affect farming systems. Understanding climate change and its causes can help mitigate it and thus improve community livelihoods through improved farming systems. Unpredictable Rainfall patterns reduce crop production. Most climate change predictions indicate variability of weather seasons (IPCC, 2014) Agricultural productivity is highly sensitive to changing climate, affecting food production. Sustainable intensification and agricultural diversification is a better way of improved food production. Deforestation causes degraded natural resource base and reduced soil fertility. The high population growth has led to commercial logging and environmental degradation.

Deforestation leads to soil fertility loss, negatively affect hydrological cycles thus impacting on crop production. It’s very clear indication that Deforestation negatively impacts the food production through increasing temperatures affecting the climate system dynamics. According to Boitt (2016) Research indicated a reduction in forest cover and a negative effect on water dynamics in the period of 1989 to 2010 in the area of study.

1.2 Problem Statement

Mau forest creates an ideal condition for crop farming due to its influence on the regional micro-climate and rainfall patterns as it covers an area of 400,000ha thus affecting the whole of East Africa both ecologically and economically.

Being a major water tower, its destruction seriously negatively impacts on the environment, hence affecting food production in the area, thus the need for knowledge on conservation is key to inform practice and enhance food production. Past studies on effects of deforestation on the environment in the Mau complex indicate that if this trend continues, then there is going to be catastrophe in terms of environmental degradation, floods, droughts, thus negatively affecting hydrological cycles culminating to reduced overall food production. Despite its national and international importance as a natural resource, the forest complex has been widely deforested (Kinyajui, 2010). It has been shown that human encroachment on the Mau Forest Complex has so far affected negatively the forest stocking, composition of species and the hydrology of the forest (Kinyanjui, 2011) in the recent decades, more than 25% of the forest has either been cut down or degraded.

1.3 Hypothesis

Deforestation has affected the climate, hence implicating on food Production in the study area.

1.4 Study Objectives

The main objective was to investigate the impacts of deforestation on climate and implications on food production in the study area...

The following specific objectives were undertaken:

1. To assess the trend in forest cover change.

2. To analyze the trends in observed rainfall and temperature changes.
3. To assess the effects of forest cover changes on rainfall and temperature.
4. To determine the relationship between Forest cover change, climate and crop production.

1.4.1 Research questions

What has been the trend of forest cover change?

What is the trend of observed rainfall and temperature changes?

How has forest cover change affected rainfall and temperature?

How has deforestation and climate impacted on food production in the study area?

1.5 The study Justification.

The study is anchored on legal framework, SDSG goal No 2 to end hunger by the year 2030,which is all about ending hunger, promote sustainable agriculture and reduce food insecurity and alleviate poverty. All of which cannot be attained in a degraded environment. Data and information on impacts of deforestation on climate and hydrological cycles is required to provide information on their implications of crop farming in the area for improved food production.

According to Boitt (2016) much has been done on Deforestation, soils and hydrological cycles in the study area but most overlook linkages to food production. It's very crucial, urgent to offer solutions for the study sought to contribute to extra knowledge in the subject area, serve as framework for policy formulation and a basis for implanting development and insights on integrated forest conservation for increased food productivity.

Without a clear data and information on the causes of deforestation and its impacts on crop production and what the current position is, it overlook environmental protection while creating awareness, making policies and enacting laws on food production in the country. It is very critical to provide reliable and a better information for appropriate planning on forest conservation and making right choice and proper planning, thus looking beyond the canopy.

Assessing climate change in the study area and relating these findings to food production provided valuable insights for sustainable forest management and future preservation and conservation efforts. Past studies have shown positive correlation between deforestation and increase in land deterioration, whereas the negative effects of deforestation on climate and its implications on food production has not been addressed adequately, hence more studies that assess the issue are required to provide enough information for law makers. There is an increasing need for food production assessment in the wake of today's challenge of climate change and variability.

Several studies carried out have analyzed effect of reduced tree cover brought about by increased population, infrastructure development among other factors (Olang and Kudu, 2011; KFS, 2013; Mistook *et al.*, 2014), the area is chosen to bring a clear picture of environmental degradation negatively affecting crop productivity. Past research done on assessment of effect of deforestation on water cycles in Mau forest whereas the issue of food production was not addressed.

1.6 Description of the Study Area

South West Mau is one of the most deforested and most endangered among the other Mau blocks (kfs 2010). The forest complex forms the source of important international rivers such as the Nile, Mara and Ewaso River which are economic life lines for some sections of a country's GDP: Tourism, Agriculture, and Hydropower generation (GOK, 2009). Over 100,000 hectares of the forest has been destroyed in the earlier years largely due to forest encroachment (Gathuru, 2015).

According to (Hesslerova *et. al* 2011), Deforestation of Mau forest has led to a negative effect and ecological dynamics and Lake Catchment. The estimated number of households in South west Mau is 13,000 and their source of livelihoods is crop production (UNEP 2008). A report by landscapes project Kenya (ISLA 2016), given the high rate of land requirement and forest products in the area, rapid human population growth in the region, all of the forest must be considered under severe threat at this time. South West Mau cover about 84000 ha, about 20% of MFC total land is critically important and is the largest of the 22 forest blocks of the complex.

1.6.1 Geographical Location

South west Mau coordinates - 0°34'60" S, 35°25'0" E, reserve lies within 0.5˚ south of the equator and between 2000 m and 2800 m in altitude. The forest feature classification is tree vegetation type.

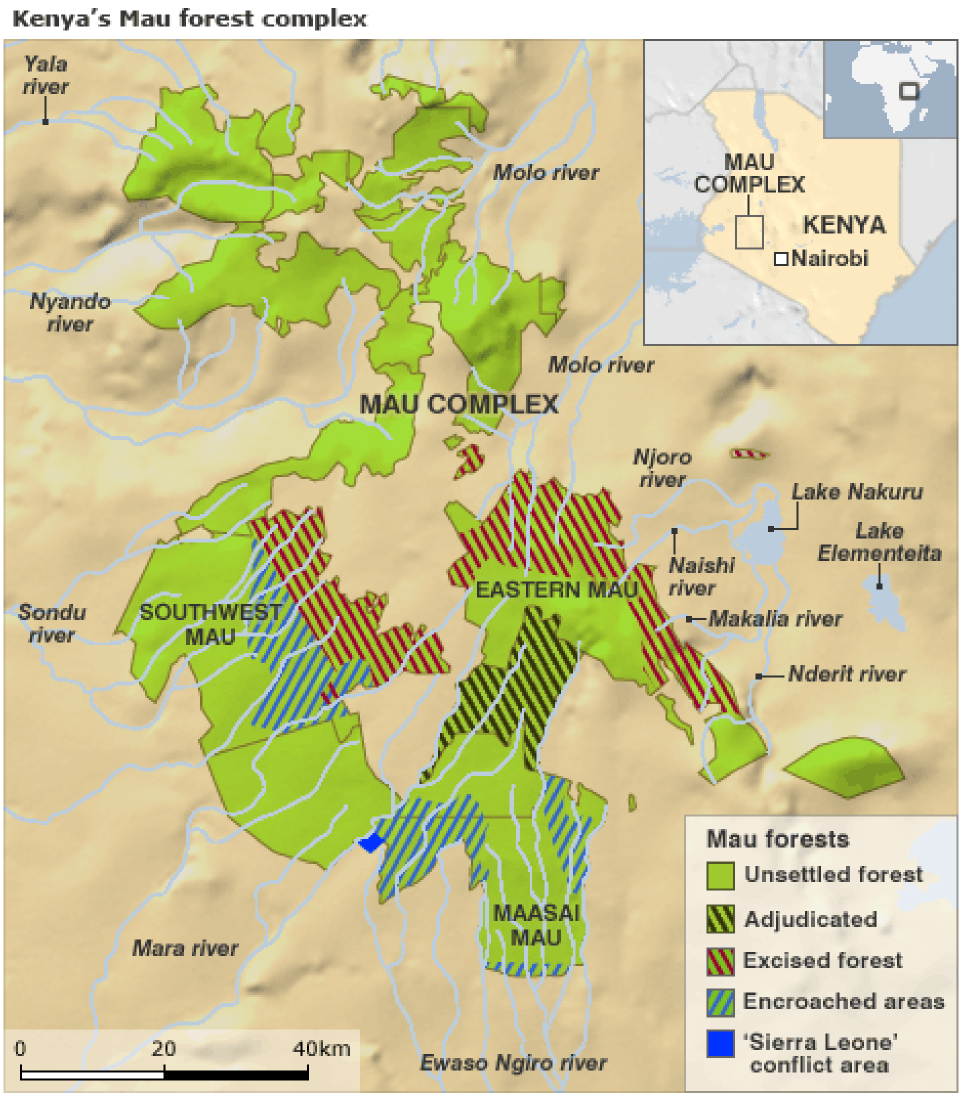


Figure 1: Map of the South West Mau. Source: (GOK, (2010a): Rehabilitation of the Mau Forest Ecosystem Programme)

1.6.2 Land Use

The main land use activity is agriculture (Mixed farming-maize, beans, potatoes, peas).The main economic activity is subsistence farming with some crops for sale and is entirely depended on rainfall for livestock production, fishing, and industrial activities. The Forest cover change in the area is due to uncontrolled human activities.

1.6.3 Climate

1.6.3.1 Rainfall

Rainfall range between 1000 mm – 2000 mm on normal years. It has changed over the years due to change in forest cover.

1.6.3.2 Temperature

The climate area is classified as warm and temperate throughout the year. The annual maximum average temperature over the catchment area is at least 18.0˚C in all the months; temperatures are highest in April who ranges around 19.1^0C and the lowest in July. Maximum temperature range 24.1 ^{0}C – 25.9 ^{0}C Average temperatures range by 2.1^0C during the year. The seasonal difference in average temperature over the area is small (2.4˚C). The warmest month is normally February and the coldest is July with an average range of about 10^0Cin between the warmest and coldest months (Ahrens, 2009). Estimation of the actual mean air temperatures is quite complicated due to varied and different topographic features; hence the area can be described as being in a tropical type of climate zone (Ahrens, 2009).

1.6.4 Soils

The soils are of high agricultural potential due to their good drainage and fine texture. High levels of soil fertility in this area have attracted human's settlements, farming and other land use activities such as industrial developments.

1.6.5 Population

The study was carried out in two locations namely kabiaga and sotik both with a population of 11,050. Population density is 220 persons /square km. 85% of the population lives within 0-5km range to the forest and uses it directly or indirectly according to Population data – (Kenya National Bureau of statistics, 1999).

1.7 Conceptual Framework

A conceptual framework is a cause effect relationship that represents an interpretation of the literature and provides a road map to guide and explain the researcher's synthesis of literature by explaining a phenomenon showing interrelationship of various variables. Is a mode linking the physical variable deforestation and climatic variables with food production? It depicts the linkage between climate changes with food production.

Changes in normal rainfall trends and temperature variations are caused by deforestation changing rainfall patterns will deplete food harvests. The major implications of climate variability is due to unpredictable is due to both rainfall variation and temperature rise. The result of crop failure often leads not only to food insecurity but also loss of income. Deforestation impacts on climate change, for example, food production is sensitive to unbalanced hydrological cycle. Changing climate impact on the hydrological cycle. Floods and runoffs impact on soil fertility of a region leading to reduced soil moisture and dry soils, hence crop yields, all attributed to climate change due to deforestation a thus negatively impacting on farming systems.

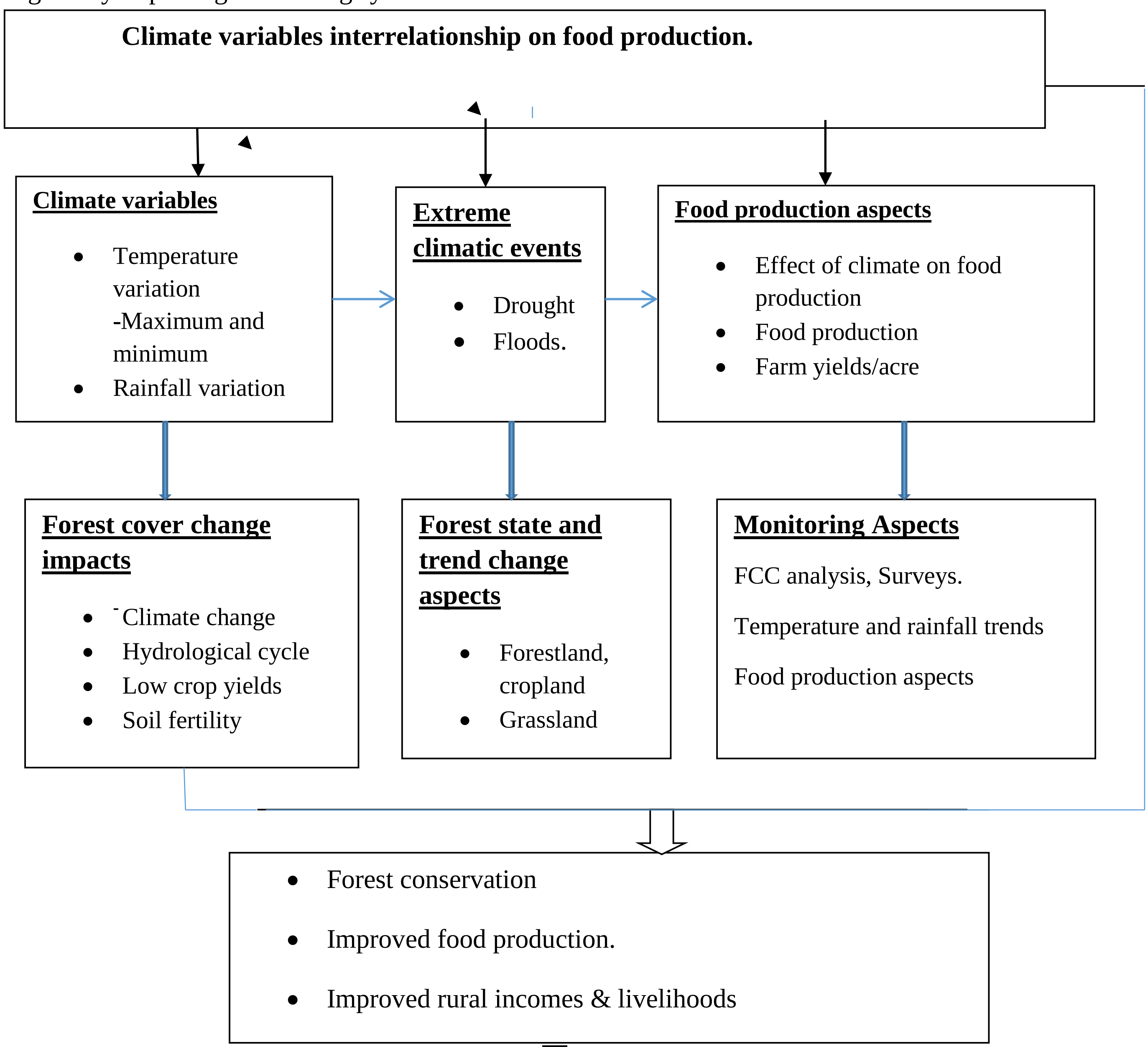


Figure 2: Flow chart procedure with linkages of the various variables of the conceptual framework. Source: Author

CHAPTER TWO

2.0 Literature Review

In this chapter, Food production, effects of deforestation on climate, effects of climate variability on crop production, deforestation, Climate and hydrological Cycle, Deforestation, Soil Fertility and Food Production are discussed.

2.1 Introduction

Change in climate variables like temperature, winds patterns, rainfall of a region observed over some years period IPCC (2007). This has an environmental, social and economic threat to community livelihoods due to its causes of flooding, drought and other extreme conditions Agriculture in Kenya is mainly rained affecting the small scale farmer

Agriculture sector is the most crucial as it provides 36% of the World's workforce. It employs 75% of Kenyan rural communities and contributes to quarter of Gross Domestic product. Food security was named the first MDG which has not yet been achieved yet; one of the sighs regarding levels of a county's development.

2.2.1 Food Production.

The key cause of hunger is inadequate and insufficient rains leading to hunger and an indicator of poverty. Sufficient food production is vital for the economic growth of any country. It's important for populations to have access to sufficient safe food supply all time. The amount of yields per specific unit of production e.g. no of bags / acre is a measure of food production.(Awour *et al.*,1997).

Extreme and unpredictable weather patterns have affected crop yields in Kenya and Africa alone food production could decline by more than 30% by the year 2050. (Juma, 2010).

Population increase has effects on sufficient food production at the wake of climate change .Global demand for food in countries with increasing populations will continue to rise due to competition for water and land resources like in Kenya hunger is projected to rise due to declining arable land. (FAO, 2009)

Adequate production of food is determined by changes in rainfall patterns and increased temperatures. Insufficient food production translates to a high level of susceptibility to famine and hunger, extreme events are on the rise as climate variability and global warming takes hold. (FAO, 2004). Insufficient food production leads to unhealthy human conditions, low productivity, poor physical and cognitive development and high death rates and is directly interrelated to poverty about critical thresholds in many regions .Forests are critical for food ,fuel and livelihoods for over 1.6 million people living in poverty worldwide. (Kabara,M.*et al*.,2011).

Communities like forest dwellers who are subsistence farmers with landless families are the most affected by poor crop production, suffer from chronic hunger and poor nutrition. Insufficient food production is of a major concern to the scientists, researchers and the governments, food production in a climate change scenario is a major problem for society, (Vick, 2012)

Sufficient food production is the physical and economic reliability. And an access to food on a sustainable basis both for human wellbeing and economic development. Enough food production leads to increased productivity, physical and good development and reduced mortality rates. (FAO, 2013)Enough food supply is of national discussion and of importance pertaining to development and poverty reduction (Vink, 2012).

Sufficient Food production is a key indication of social wellbeing, decreasing hunger lead to increase in economic performance through human productivity. Food sufficiency is anchored on stability of resources and sustainable food availability (Gregory *et al.*, 2005). The world’s poor particularly the forest dwellers, small scale farmers, squatters and livestock keepers are the communities who adversely suffer due to their over dependence on natural resources. Regions currently experiencing insufficient food production are expected to have a disproportion across a wide range of human activities. (Ngaira,J.K 2009).

2.2.2 Effects of Deforestation on climate and variability.

Research on impacts of such land cover changes according to (Hesslerová *et al*. 2011) which indicated that land cover change has caused decline on precipitation levels of the affected regions and have degraded the ecosystem in the area. (Ayuyo 2014).Human population influx over time has led to many negative effects on land cover change, thus impacting on agriculture. Natural resources are dwindling quickly and this is felt through the number of communities affected by hunger and food insecurity (Cifor 2014).

Due to its effects on Mother Nature, Deforestation is an expression of social injustice (Colchester and Lohmann, 1993). And these are some of its drivers. Growing populations leads to upsurge of towns and cities for development that call for expansive land to give way for development infrastructure to support urbanization leading to clearing of forests (Mather, 1991, sands, 2005). Roads, burning of charcoal, buildings, and fuel wood gathering are common in forests in developing countries with the poor populations (Boitt 2016).

It is always asserted as “evil “because of the long-term environmental impact for sustainable development as evident in climate change effect on hydrological cycle and soil degradation, 20%. Land use change is a primary forcing of climate change at both regional and global scales. Cutting of trees over a large area for agriculture use, commercial logging, charcoal burning and human settlements, forest encroachment and urban development is deforestation (Nautili 2010).It is also a process whereby trees are felled without replacement.

It is estimated by UNEP that almost close to 107,000 hectares of Mau complex which is a quarter of its total forest cover was lost in the years between 1991 and 2011.Seasons variability will become more intense (IPCC, 2012; Omondi *et al*., 2013). Slash and burn practices, unsustainable hunting can lead to uncontrolled fire outbreak that destroy forests and animal species, thus negatively impacting on soil fertility, biodiversity and water loss due to forest degradation. 60% is cleared for agriculture, 40 % for logging, infrastructure, urbanization, fuel wood, Overgrazing, fires, mining, corruption, political use (Anon, 1994).

Deforestation leads to unpredictable weather conditions like drought which is a key driver to poor food production, severely affecting farming systems (Milleretal.2011). Excisions and wanton encroachments of Mau forest reserve have impacted negatively on the hydrological cycle the forest cove r stood at 7% (WARMA, 2009)

Nationwide according to Kenya forest service (2013) and deforestation must be controlled to avert biodiversity loss and changes in hydrological cycle. (Were *et al*., 2013). Yields are affected by microclimatic changes due to poor soil, soil erosion and biodiversity loss. A study of Mau Forest reserves by UNEP/KFWG (2006) has shown South West Mau as the most deforested of all the blocks comprising the MFC and has proposed reforestation and rational land use as some of the measures needed to curb the degradation of the MFC catchments. (GOK 2007).

Deforestation has led to climate change, increased temperatures, and hence changes in rainfall patterns, growing seasons, rainfall becoming unpredictable, unreliable rainfall leading to huge losses to farmers due to post harvest losses. Forest cover size in Mau has been decreasing due to deforestation taking place there. Thus affecting the soils and water cycle and leading to negative effects on agriculture sector (Boitt 2016). Between years 2004 and 2007 a decrease of over 10800 ha of forest cover was witnessed in this 400000 ha plus forest complex (UNEP, 2009a).

Population influx has led to clearance of large chunks of land. Deforestation has increased due to the anthropogenic activities-which lead to environmental degradation, it leads to loss of biodiversity thus no wild fruits, wild meat, nuts, fibers and resins which are readily available foods, deforestation causes localized flooding leading to negative effect on sustainable development (Olang *et al*., 2010)

Loss of several hectares of forests yearly severely impact on ecosystem services, weather regulation both local and global levels. (FAO, 2010). Forests depletion widely affects all aspect of society, yielding some of the most systemic and complicated feedback that frustrates human progress and negatively impacting on sustainable development (Islam and Sato 2012).

Massive carbon stores are activated through afforestation as global warming is activated by deforestation (FAO, 2010). Extreme weather events like storms floods and drought. Urgent measures are required for sustainable forests management. Its control leads to conservation of valuable services-erosion. For a stable agriculture production pollination is very important... Deforestation is a disastrous consequence for the climate and food security, trees cools the atmosphere and store greenhouse gases. FAO, 2010 estimates that 30million acres (13m) hectares are lost yearly and forests are home to 70% of the earth's biodiversity, and Billions of pollinator bees have lost their habitant .Forests are important in contributing to a country's development in terms of agriculture.

Burning of forest to clear land like slash and burn agriculture releases huge quantities of carbon dioxide which impacts on the global environment through global warming (Scherr *et al*, 2005). Slash and burn agriculture causes reduced canopy due to reduced density and burning of organic matter which dry up due to accelerated ignition of forest fires.

Cleared land is more susceptible to temperature extremes, which some crops may not tolerate. The world poor population entirely relies on forests for livelihood, source of income, food and fuel wood. Global warming has disastrous consequences. Biodiversity, habitat, and natural resource depletion thus affecting food production. Forest clearance affect the climate system by affecting the ozone layer though reduced carbon dioxide absorption and thus increased temperatures. Deforestation leads to increased soil erosion due to exposed ground, reduced catchment area and water holding capacity, loss of biodiversity and habitat loss, reduced soil fertility, flooding, exposure of soil to heat thus affecting food production. It also leads to reduced water quality and quantity and availability, thus no water for irrigation.

Tree cutting lead to increased emissions and concentration of gases, hence high temperatures as forests are carbon sinks which in turn lead to crop failures. Which trap more heat into the atmosphere, thus increased weather variability. Open ground will risk crop destruction from strong winds global warming has much effects on crop, livestock and fisheries production and will affects life cycle of insects and increased occurrence of pests. Open ground leads to increased heat on the ground, minimizing and affecting moisture retention and recharges in the soil.

2.2.3. Effect of Climate Variability on Crop Production.

Changing weather seasons disrupts farming systems everywhere in Kenya mainly through variations in the timing and the amount of rainfall received. Evidence of climate variability has become more pronounced through the alternating cycles of droughts and floods. Africa is one of the regions adversely vulnerable to weather variability. Kenya's ninety eight percent of its farming systems are rain-fed (UNEP, 2009).

Temperature rise today due to global warming. Adverse effects of climate variability in many regions thus negatively affecting crop farming (IPCC, 2014). Unpredictable rainfall patterns coupled with extreme weather events have continued to impact on the natural resources. As the backbone of Kenya's economy, the agricultural sector is extremely vulnerable to climate change. Crop yields are damaged when extreme daily temperatures reach a certain threshold (Schlenker & Lobell, 2010). Evidence of such has become more pronounced being characterized by alternating cycles of seasons and impacting negatively on food production.

Climate change aspects encompass the changes in the timings and the amounts of precipitation, temperatures and wind patterns (IPCC, 2014).These changes comprise of the amount, frequency intensity and nature of precipitation. Reduced agriculture production has affected community livelihoods.

Weather variability and other factors impacts on food production are much observed during the start and end of rainfall seasons. . Moreover, higher temperature causes more evaporation reducing the amount of water available regardless of an increased precipitation (Melillo *et al*., 2014). As climate changes, the probability of certain weather events occurring are also affected, thus affecting food production. The hydrological cycles and regimes within watersheds are altered by the climate change at global scale and also local scale which undesirably impacts forests, water resources, sustainable agriculture, environment and ecosystems (Rwigi, 2014). Higher temperatures cause more evaporation reducing the amount of water available to crops regardless of an increased precipitation (IPPC, 2014).

African region is the most affected by climate variability worldwide where Kenya is inclusive as almost all the agricultural activities in the country are rain dependent. Unpredictable rainfall patterns have drastically reduced farm production.

Climate change has led to reduced yields due to decline in productivity due to heat stress on crops. This is caused by Green House gas emissions and destruction of water catchment areas by deforestation, forest degradation, illegal logging and settlements and encroachments into the forests (IPCC, 2009). In this study, the global warming affected Water availability, soil nutrients and optimal temperature of the crop for reproduction and growth, controls the effects as a result of increased temperature (Mogaka, 2006). Agricultural activities largely depend on water resources. Farming in the study area will be altered, thus affecting the economic growth of the country. Farm yield is also affected by higher atmospheric concentrations and extreme weather conditions. Increased risks to rural livelihoods are manifested by such effects; it has impacted on rural incomes, contributing to low infiltration of soil, increased incident of insect pest leading to income of communities decreasing thus increasing vulnerability.

Natural resources have deteriorated and if the trend continues will impact on food production by 30% by the year 2050 due to extreme and unpredictable weather (Juma 2010). Extreme weather conditions like drought are caused by the stretched imbalance between evaporation and precipitation (Melillo *et al*., 2014).

Food insecurity due to increased crop failures leads to income loss and low community livelihoods sources. Deforestation and climate change act in concert leading to poor food production. According to IPCC 2012, has unpredicted that rising extreme weather patterns make farming even more risky. Biodiversity loss has led to reduced food production and these are some of the threats caused by clearing of forests in Kenya. Poor or failed harvests result due drought and floods which in turn result to poor food production, Pests, livestock diseases prevalence all culminating to food insecurity. (Lobell *et al*, 2011), Climate change is an issue affected largely by deforestation. Tree cover loss affects winds flows and cause increased solar radiation, which affects ability to produce food in multiple ways. (Chomitzetal, 2007), thus increasing volatility in food production. Increased frequency of occurrence, duration, dry spells becoming more, and changes in timing, unpredictable rainfall patterns, location and amounts of rains. Increased shortages impacts on livestock production (Thornton *et.al*. 2010).Droughts cause severe interference on the economy, water resources, food security and the environment. Crop loss is due to increase in surface temperatures. Climate change adversely affects food production putting communities at risk and vulnerable to food insecurity. Crop yields are affected by higher atmospheric concentrations and extreme weather conditions e.g. flood and drought (Funk & Brown, 2009).

Majority of rural populations depend on farming which is a main income source. Increased temperatures have impacted on rivers sources, causing melting of caps in Mt .Kenya, thus rivers sources from there have dried up (Ramin and Mcmichael, 2009), Impacts of drought are manifested in poor crop yields and animal production leading to reduced food harvests, starvation and loss of livestock (Ngaira, 2005), drought causes wilting of crops, stunted growth, hence crop failure and low animal production.

Climate variability has increasingly led to flood and accelerated soil erosion (IPCC, 2007), thus impacting on agriculture production negatively due to depleted nutrients needed for plant growth. Deforestation negatively impacts on the climate system, Ecosystem services which are vital for agricultural productivity like clean water, Pollination, Fodder, Biodiversity, pests and diseases control, pollution, climate regulation, stream flow, wild fruits, nutrient recycling and moisture retention. Food production is climate dependent economic activity.

2.2.4 Deforestation, Climate and Hydrological Cycle.

The more forests are cleared, the more the risks on food production due to changes in temperatures. Deforestation causes accelerated soil erosion due to open grounds, causing accelerated surface runoff, reducing soil capacity to absorb nutrients in the long run hence reduced crop production (Chrispine OM *et al*, 2016). Water controls growth of crops through its availability related to soil moisture and nutrient transportation.

According to Boat (2016), Hydrological cycles have been affected by reduced forest cover and runoff, thus impacting on farmlands production and the trend will be on the rise. Projected increased climatic changes have significant consequences due to the alterations of the weather patterns, hydrological cycle, thus affecting the timing and magnitude of runoff, ecosystem dynamics, social and economic systems. Crop yields are reduced by the increasing temperatures which causes increased evapotranspiration (IPCC, 2014, Kings *et al,* 2012).

Open areas become sources of accelerated surface water runoff overland, reduced infiltration leading to increased subsurface flows carrying top soils. The loss of forest cover contributes to less infiltration and hence less storage of water for release for food production during the dry seasons. Forests have value in conservation and regulation of water supplies, soil conservation, and maintaining the natural flow regimes of rivers. Precipitation and temperature variations have implications by altering in water cycle and crop yields.

When natural forest vegetation is converted to human settlements and other land uses, both opportunities for infiltration and storage are greatly reduced in the long term as a result of subsequent soil compaction and the high rate at which precipitation reaches the ground surface; often exceeding the infiltration rates. (Kinyanjui, 2009). Due to precipitation and temperature variations will have implications by altering in water cycle and crop yields will be reduced by the changes in the climate in the long term. Water cycle due to runoffs as a result of deforestation has reduced water for agriculture.

Clearance of forests has reduced water interception leading to reduced streams quality and quantity in the catchment, thus affecting hydrological cycles and water supply for agriculture. Hence affecting crops growth (Olang *et al,* 2011). Reduced forest cover affect atmospheric circulations, affecting rainfall patterns, thus leading to crop failures. Global warming due to deforestation poses serious risks for both Rain fed and irrigation agriculture due to accelerated evaporation. (Aragau, 2012).

Deforestation accelerates surface runoff which carries a lot of soil downstream leading to soil infertility. Trees drill water into ground and into underground aquifers where it acts as a store to supply rivers during dry season, all rivers dry up due to reduced forest cover resulting to reduced or no food production, fish and animal production, Deforestation disrupts global water circulation) resulting to drying of crops and pastures (Bruijnzeel, 2004). It makes the local hydrological cycle and catchment area less strong resulting to reduced evapotranspiration and moisture circulation makes the hydrological cycle less strong Low infiltration capacity can have a long term effects with severe cases of drought and desertification. (Miadment, 1992; chemilil, 1995. Deforestation lead to a change and alteration of the hydrological cycle over an area when a natural forest is converted into other land uses (Muhati *et al*; 2008). Reduced moisture retention capacities and ground water recharge of a system are caused by bare ground resulting from removal of a forest from a catchment hence reduced water retention capacity. Negative effects on the hydrological cycle leads to both agricultural and hydrological droughts thus low crop and animal production

2.2.5 Deforestation, Soil Fertility and Food Production

Deforestation leads to open ground cover, causing soil fertility loss leading to negative ecological and economic effects .Nutrient loss, poor soil structure and organic matter are washed away hence low crop yields. Decrease in shear strength of the soil is caused by increased soil erosion on the surface due to open ground and so no crop survival (Swanson, fridrksen, Mc Corison, 1981).

Runoff is a main cause top soil of loss and so trees protect the soil against erosion thus preventing nutrient loss by increasing ground water recharges. (FAO, 1993). Proper water recharges helps to sustain water supplies which is very crucial for sustained agricultural production.

The leaves of trees trap a lot of rain water thus increasing ground infiltration; control runoff preventing nutrient loss Open tree cover rapidly degrades a site leading to nutrient loss. The impacts of a changing climate are evident through increased droughts and floods, resulting to rapid soil erosion and fertility loss, hence crop reduced yields. Increased soil erosion affects water quality and crop production, deforestation and accelerates raindrop impact on soil through increased velocity and wind flow reducing humus content and subsequent loss of nutrients (William D Nordhaus, Joseph Boyer 2003).

CHAPTER THREE

3.0 Data and Methods.

In this chapter, data availability, data quality control, Forest cover change, process of acquiring images, image classification, Process of acquiring data, time series analysis for climate data, population and sampling process, Primary data, Surveys, interviews, focused group discussion secondary data and correlation coefficient are discussed .

3.1 Data Availability.

The length of the data is 30 years.

The data types are:

Variable	Type	Source of data
Forest conversion(dependent)	Binary	Land use classification maps of landsat imagery
Rainfall data(independent)	Continuous data	Kenya meteorological department
Temperature data	Continuous data	Kenya meteorological department

The data was compiled from various sources which included among others, meteorological data from Kenya Meteorological Department (KMD) Temperature and rainfall data for 30 years, Forest cover change data from University of Nairobi Geological Lab for a period of 30 years and compared with data from Kenya Forest Service (KFs) in form of processed LANDSAT satellite imagery.

3.2 Data Quality Control.

Validation reasons of validation are poor road network, extensiveness of study area and limited time. Identify methods of image segmentation and classification and apply accuracy assessment Vita *et al*. (2014). Forest cover change and analysis was assessed through satellite imagery. Use of satellite images changes whereby remote sensing provided ways and means to do so according to (Roy *et al.*, 2002).High resolution satellite images are crucial in presenting data on the distribution of forests. Secondary data to verify the above information was obtained from the forestry department and from Department of Geology university of Nairobi.

3.3 Forest Cover Change

Forest cover change maps, used in this study according to (Vita *et al*., 2014), were produced from Landsat satellite images and fieldwork data was collected to validate these maps and multiple datasets. Analyses of remotely sensed LANDSAT imagery were used to obtain land cover datasets for three time periods of 1988, 1998, 2008 and 2018 and on account of their accuracy, affordability and accessibility. LANDSAT satellites were used to provide cover change (FCC) datasets for the study. The three processed LANDSAT imagery from Geological laboratory compared with data from Kenya forest service. (KFS). The raw satellite data was converted into the maps for 1988, 1998, 2008 and 2018 and presented in digital form. GIS technology enabled evaluation of the change, trends and magnitude. The area was subjected to the forest change where analysis of the classification and overlay operations were carried out.

GIS monitoring technique was used and remote sensing, the study utilized forest cover changes The Landsat imagery were classified into intervals which are reasonable to give substantial changes in forest cover, indigenous knowledge with past experiences on forest cover changes was utilized to provide cover change trajectories. LANDSATE satellite imagery is a freely available, medium resolution and of good quality (Kenduiywo *et al*., 2013).

The remotely sensed Landsat information assisted production of the maps. High resolution cover change datasets provided different maps for the area. For cover changes, the study involved data acquisition, processing, analysis and interpretation activities. The years selected for the cover changes depended on the availability of the satellite images. Classification was applied on four land sat images of 1988, 1998, 2008 and 2018 with classification scheme of min class of forestland. Information on the trends, magnitude and rates was done through classification of visual area comparisons... The findings of the study showed drastic reduction of forest cover over several years.

The data for 1988, 1998, 2008 and 2018 images were overlaid and the magnitude of change computed for the (1988-1998-2008-2018 period), from which forest cover change during that duration was extracted. Analysis was carried out on trend of forest cover change by identifying the activities contributing to these bands e.g. 4 (infra-red), 3 (red), 2 (green), which were represented by infra-red, red, green respectively. The bands help in vegetation enhancement, color contrast and also give more information. The combinations of these bands were used in forest cover change analysis. In addition, true color composite was also formed to aid.

3.3.1 Process of Acquiring the Images.

Downloading images from United States Geological Survey (USGS) for 1988, 1998, 2008 and 2018. The images were produced and a band composite developed. The image was masked with a shape file layer representing the boundaries of the study area. The band combination was performed i.e. (4:3:2) representing infrared and green wavelengths that are known to represent vegetation. The spatial resolution of LANDSAT imagery and the fact that it is multispectral makes it a suitable source of data for environmental and climate studies since various band combinations provide information on the land surface and its properties.

3.3.2 Image Classification

The images were grouped for the years 1988, 1998, 2008 and 2018 which were from four different epochs, processing and comparison of forest - cover change (FCC) tabulated .Area of interest was clipped out from the images for interpretation. Visual interpretation was done by segmenting the raster (vectoring raster image into shape files for classification). Interpretation of these segments was done for all the years based on the interpreter's skills and knowledge as well as using available data.

3.3.3 Processing Of Satellite Data.

This involved clipping of the data from the selected area. Forest Cover Change maps (FCC) and correction of lines through georeferrencing and clipping of south west Mau coordinates - 0°34'60" S and 35°25'0" E,

3.3.4 Time series analysis for climate data.

Monthly rainfall distribution and temperature trends were from five selected weather stations around the area. The monthly and annual records of rainfall, Temperature were obtained from (KMD) in five selected rainfall stations, whose selection was based on the length of data records. The observed annual cycle of mean monthly total rainfall and temperature over the period 1987 – 2017 was from five stations within the area. Data used for the calculation of the trends of the past climatic years. Some data was also collected from household surveys to get views from the farmers as to how they think climate change has occurred in the past years. This was made to compare the responses with the observed data from the stations.

Table 1 : Rainfall stations used.

No	Name	Code	Latitude	Longitude	Altitude (m)	Remarks
1	Bomet	9035265	-0.7833	00	1951	Length of record
2	Kaisugu	9035075	-0.3167	35.3666	2134	With highest latitude
3	Kericho	9035279	-0.3667	35.2700	1973	Length of data record (30years
4	Keresoi	9035240	-0.2833	35.5334	1828	With lowest latitude
5	Timbilil	9035244	-0.3500	35.100	2074	Length of data record(30yrs)

The trimodal pattern of rainfall was attributed to the geographical location of the forest complex. Due to this and uncertainties related to errors of measurement and missing data. For the studies over large areas, satellite based rainfall estimate is used by the Kenya meteorological department to acquire information.

The observed datasets for rainfall and temperature used was acquired from Kenya meteorological department. Effects of temperature and rainfall on food production were considered owing to their long term impact on seasons and climate variability.

Monthly time series data were collected and aggregated into monthly and yearly totals. Five rainfall stations located in and around the area of study were selected to provide the required datasets and for comparison purposes. This was based on the length and the quality of their data records in the area. The stations were well placed for high quality and dependability of the data.

The datasets for years 1987 to 2017 from Kenya Meteorological Department (KMD) on a monthly time scale were used. They were processed to get the monthly average seasonal rainfall and temperature trend analysis since crop production is done only on either long or short rains. Owing to the differences in topography and the placement of the rain gauges, the density was considered representation of rainfall induced processes. Due to this and uncertainties related to errors of measurement and missing data, the Department has put measures in place by using the satellite based rainfall estimate. The existing rain gauges and the density were considered representation of rainfall induced processes for studies for large areas and the results related to crop production, this was due to diverse topography of the area.

The data sets were processed to get the monthly, seasonal and annual for all the datasets. These were observed data values from different meteorological stations. The annuals average (max), (min) temperatures were determiner period 1987-2017 and used to show the distribution of rainfall and air temperature over the catchment which helped in understanding the past and present climate characteristics. The observed datasets for rainfall and temperature used in this study were acquired from KMD and some also collected through household surveys to get views from the farmers as to how they think climate change has occurred in the past years. This was made to compare the responses with the observed data from the stations.

The results then analyzed for trend changes and presented in figures. Graphical methods included the time series analysis with the past trend assessment for the observed (rainfall and temperature) for the period 1987-2017. MS excel used for analyzing temperature and rainfall organized into tables, frequencies and percentages. Data obtained was displayed in form of maps, tables and graphs.

3.4 Population and Sampling Process.

The household heads were the target respondents. Area was purposively selected due to the proximity to the forest and was highly impacted by illegal encroachment and tree cutting. This is also the area where the highest number of rural households depends on agricultural, livestock production and forest for their livelihoods. The locations bordering Southern Mau forest were picked randomly for this study mainly because of the limited resources (time and money) available for research.

3.4.1 Primary data

Study area was Kabianga and Sotik Locations consisting of a total population of 11,050 people. This includes first-hand information sourced from the opinions and views of the residents and resource persons in the area. Primary data Sources were:

3.4.2 Surveys.

These gave information on the factors affecting food production. Target number of people for this research established. To conceptualize phenomenon under study and set the most reasonable sample size from the total population to ensure that all the information from various sources was captured.

Random sampling was used in choosing the first household to be interviewed. When population is more than 10,000 individuals. The method below is used when the population is more than 385 according to Mugenda ,1999)

NF=n-1

$\mathbf{nf} = \frac{\mathbf{n}}{\mathbf{1}+\frac{\mathbf{n}}{\mathbf{N}}}$………………………………… 3.1 was used to calculate the sample size. Where,

$\mathbf{nf}$ = desired sample size when population is more than $\mathbf{10,000}$

n= desired sample when population is more than 10000

N= Estimate of the population size;

$\mathbf{nf} = \frac{\mathbf{384}}{\mathbf{1}+\frac{\mathbf{384}}{\mathbf{295}}} = \mathbf{167}$…………………………… 3.2

According to Kombo and Tromp, (2006), minimum acceptable size of the sample is dependent on kind of research. Respondents were identified and selected within a 5 kilometers radius, as cited by Kiragu, and (2002) assert that the impact and dependency of the communities to the forest decreases with distance from the forest. The crop production per household was estimated per plot per crop since most farmers practice mixed farming.

The Kenya Indigenous Forest Conservation Program - KIFCON studies (1994) also indicated that the greatest interaction of the community with the forest is by living within the radius of 10km from the forest. But considered 5km radius coverage to identify, pick houses living adjacent to the forest. Simple random sampling technique is appropriate for this study because it provided 85% representative sample that was used to generalize from the specific sample to the population representation (Bryman, 2008). It is a convenient technique to use since there is minimal chance for human bias to manifest itself a survey questionnaire was administered for the quantitative data.

Open ended questionnaires were used to allow for qualitative discussions with the household concerned. Questionnaires used ensured anonymity and allowed use of standardized questions with time provided for subjects to think about responses and hence provide quantity and quality data, which was analyzed. The questionnaire and the checklist were pre-tested. The questionnaire consisted of questions on the subject matter to address the objectives.

A key informant guide was used to provide overall direction for interview. It consisted of open ended questions to elicit responses and give more information regarding the study. An in-depth interview was carried out with the informants. The questionnaire contained questions about demographic characteristics, household information and the factors affecting food production in the area. Careful and logical scientific standpoint of the study was considered as it is very critical. Completed questionnaires were cross-checked for data integrity and data cleaning. Data was coded for analysis along key themes, emerging patterns and consistency.

The study was conducted using research questions to guide the assessment. A descriptive survey design as defined by Kombo and Tromp (2006) method was used to collect data where representative samples of the total population were collected. Data derived from actual field observation were intended to be compared with that from the respondents on topic in question.

3.4.3 Interviews.

The key respondents comprised the KFS officials, the heads of related government sectors, Chiefs and assistant chiefs, Village Elder who also heads the local organization. They were chosen on the basis of their expertise and experience on issues under study and were able to provide information on forest conservation and livelihoods.

3.4.4 Focused group discussions

This was carried out through community forest associations (CFA, s) who live near the forests and are involved in forest management, Non-Governmental Organizations.

3.4.5 Secondary Data

Extensive review of secondary data sources was carried out to inform and furnish primary data collection. Utilized the findings and results from various sources from the study to assist me achieve the overall goal. This was done on published, online, reference books, Magazines, Research gates, scientific papers, publication .Made to add more knowledge onto theoretical and empirical literature on deforestation.

Data was acquired from the ministry of agriculture on the status of food productivity and soil fertility issues in the area and how the production has been over years; this was to compare with the response from respondents. (Crop data). And reports from ASDSP, ISLA, and UNEP were used. Statistical Software package version 22.0 Qualitative data analyzed by content analysis and thematic analysis and coding interpretation done along key themes to determine its relevance. The findings presented in tables, explanatory texts, frequencies, percentages and summary statistics to show relationships between key variables. Finally, the data findings were processed through various techniques.

For the questionnaires and interview schedules, SPSS was used for frequencies and cross tabulation for perceptions done using a fixed methodology to make sure that the reexamination of the facts are comprehensive, transparent and replicable. In addition to searching electronic databases, examination of websites, academic papers, practitioners and researchers for relevant research was carried out.

3.5 Correlation Coefficient analysis

Conducted to analyze relation of climate variability and forest Cover Change. It gave an idea of how well the data fits a line or curve. A (+0.50 -   + 0.80) is a positive linear correlation. It measured degree of association between variables. It also showed how strong the relationship is.The linear correlation is positive when it is between +0.50 and + 0.80.

CHAPTER FOUR

4.0 Results and Discussions

Deforestation rate, comparison of the forest covers change between the result of Satellite imagery and the household surveys**,** main causes of deforestation, rainfall trends, Maximum Temperature, general information on the sampled population**,** Category of the respondent by gender**.**

4.1 Deforestation rate

The forest cover change over the years was tabulated for 1988, 1998, 2008 and 2018. The yearly cover change values were calculated in percentages. The forest reduction in terms of hacterage from the year 1988 to 1998 was reduction of 73 ha, that from 1998 to 2008 was reduced by 49405.916 ha and the increase from 2008 to date was 22801.916 ha. The reduction from 1998 to 2008. The population increased leading to more forest clearance for agriculture, illegal settlements and charcoal burning.

Table 2: Forest covers change in the area over the years in hectares and percentages

Serial No	Year	Year (Ha)	Years	Change in Ha	Change in (%)
1	2018	63643.674	2008 – 2018	22801.425	Increase of 55.83
2	2008	40842.249	1998-2008	-49405.916	Decrease of 54.7
3	1998	90248.165	1988-1998	73	0.80
4	1988	90321.165	-	-	-

It is noted that the forest cover change from 2008 to date has increased by 22801.425 ha .This is attributed to the recent massive campaigns on afforestation and protection of the water towers. However, the forest recovery is small since its afforestation is long term and it takes years for restoration of the forest to its original state, a forest is destroyed in a few years but takes many years to be restored back.

The effect on the ground in terms of improved food production is little since the forest is recovering from the massive destruction between 1998 -2008. The negative value indicates a drastic reduction in area over time.

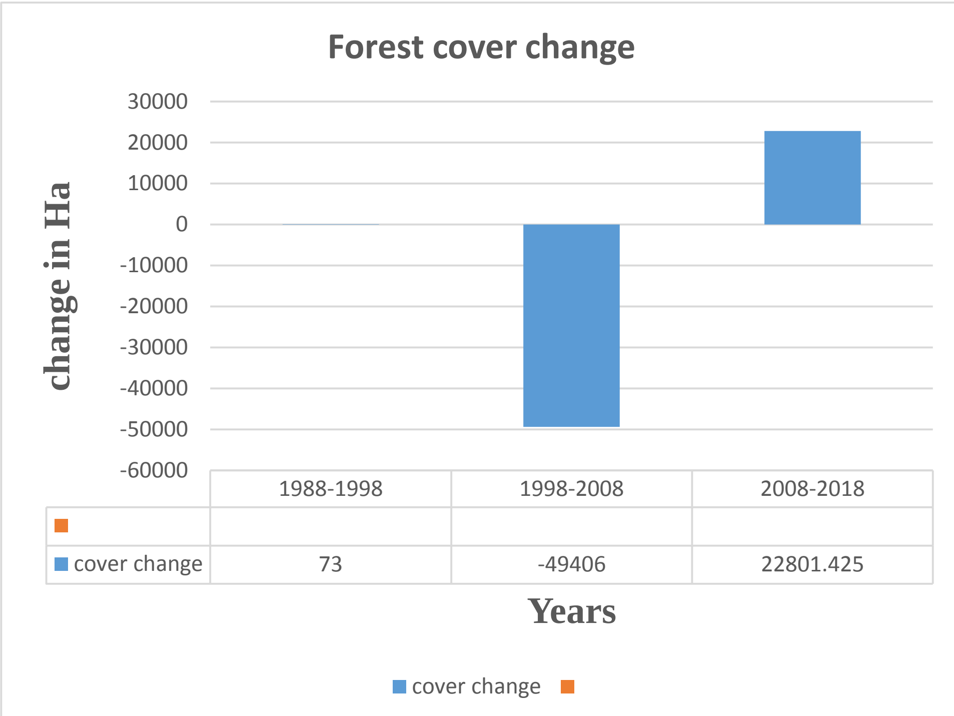


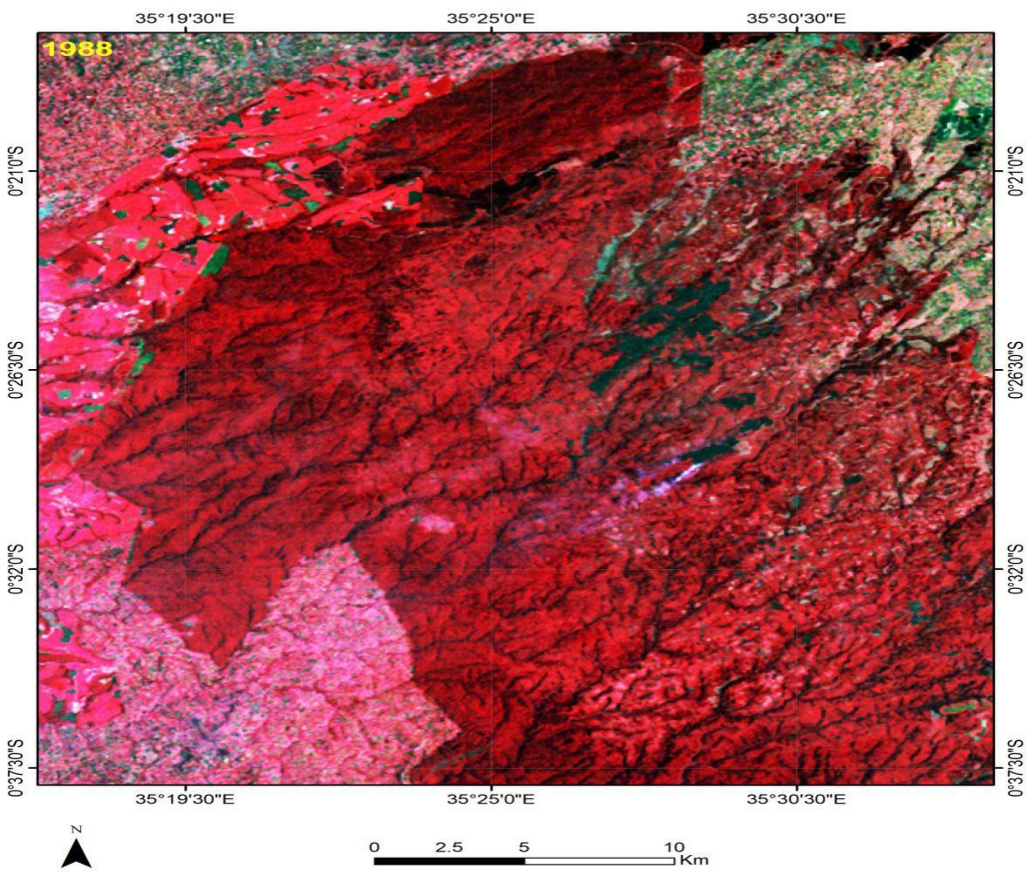
Figure 3: Forest cover change in hectares from the year 1988 to 2018 in the South west Mau

Table 3: Landsat TM data with different bandsand wavelength.

Band	Wavelength (µm)	Resolution (M)	Nominal spectral location
Band 1	0.45 - 0.52	30 m	Blue
Band 2	0.52 - 0.60	30 m	Green
Band 3	0.63 - 0.69	30 m	Red
Band 4	0.76 - 0.90	30 m	Near IR

The near-infrared band (band 4) is important in depicting and determining different vegetation classifications and their biomass content (USGS, 2009a). Monitoring land cover changes like deforestation and natural disasters are well depicted by conducting different time series analysis.

The maps representing false color infrared Landsat images were generated by combining the four bands. Dark red color represent vegetation cover and indicates the density and concentration of vegetation e.g. dense, luxuriant and concentrated vegetation while light red indicates scattered or less dense vegetation which could be as a result of stress. The green color indicates soil; brown is bare – rock. Data used to make these maps are Landsat imagery acquired from the United States Geological Survey (USGS) Website. The resolution of 30 meters. It’s crucial to demark and separate the forest use from other land uses during the interpretation of Forest cover maps (FCC) maps. Combination of green, red and infra-red bands produced the FCC maps.



The forest cover by 1988 was not much changed compared to the following years. The infrared (dark red) shows the forest cover area (vegetation) .The south east of the map is the tea plantations which act as a buffer zone for preventing forest encroachment.

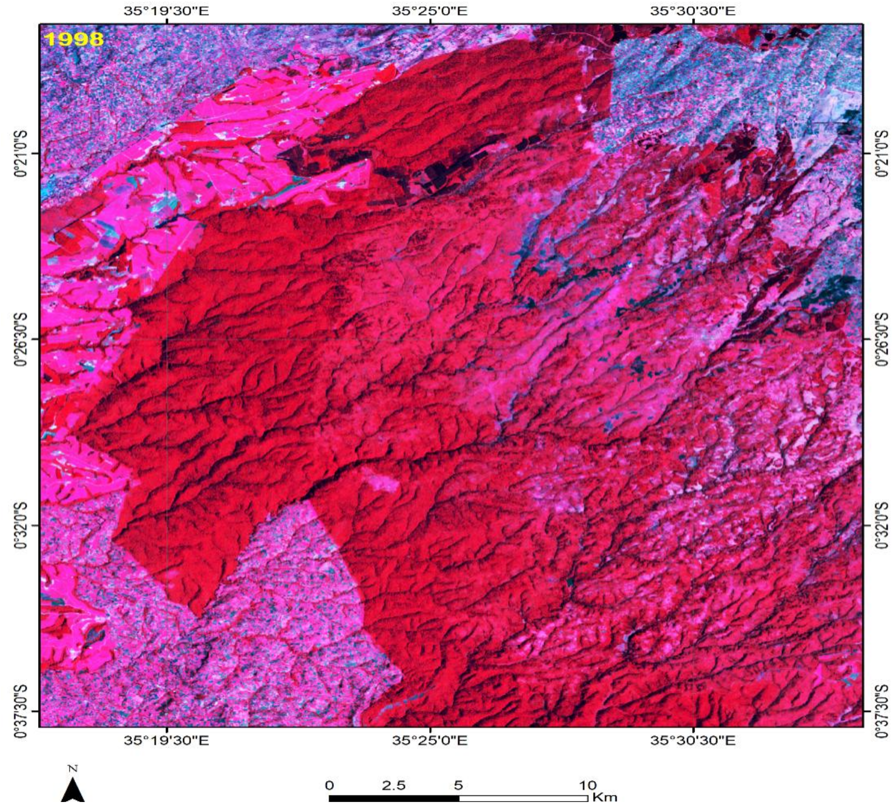


Figure 4: Forest cover change in 1998 due to changes in land use (Geological laboratory, university of Nairobi).

The forest cover had reduced by about 73 ha between 2008 and 1998 due to population increase in the area. There was increased nyayo tea zone in the area. The red brown color is the crop land around the area. The green is bare soil with some rocks

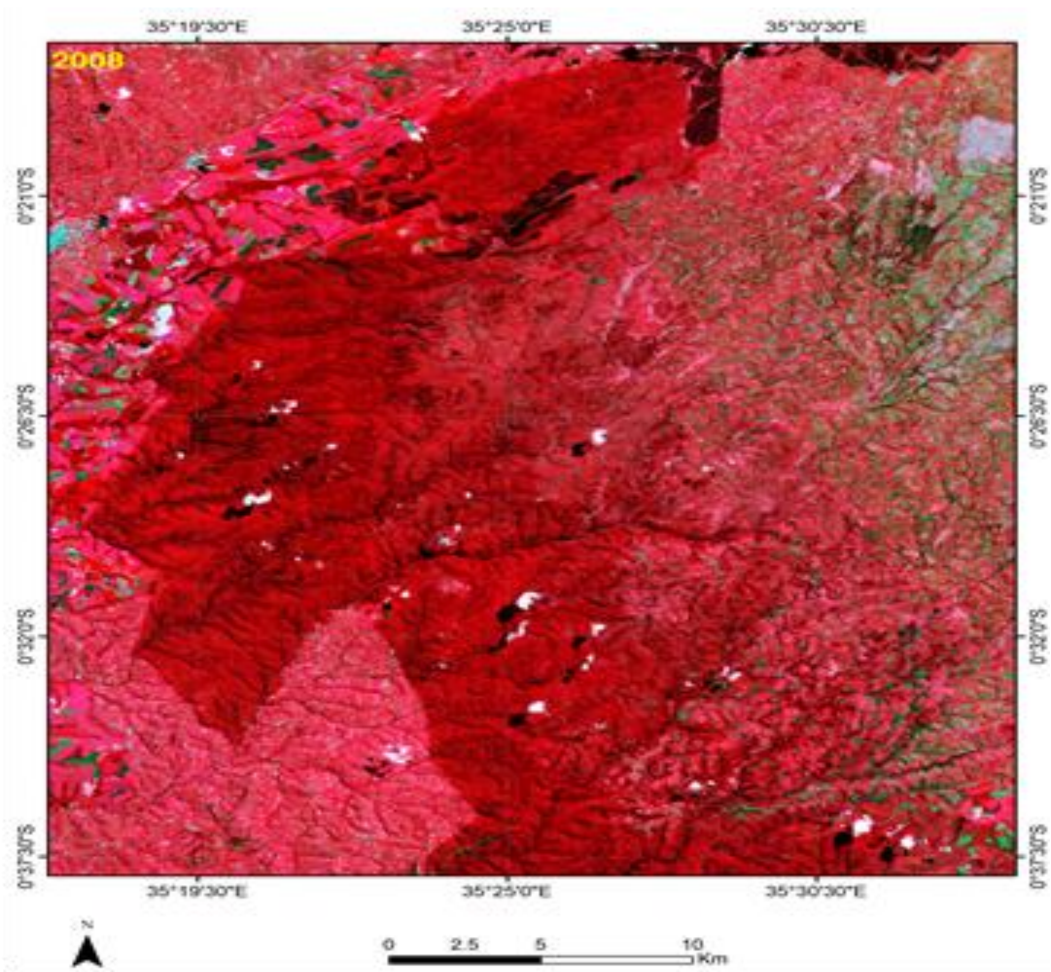


Figure 5: Reduced forest Cover in 2008 in the study area due to human interference

The forest cover drastically reduced during this period by 49,405.816 ha. There were a lot of human settlement in the area and this was attributed by the 2007-2008 political clashes in the country which led to a lot of illegal settlements in the area and population increase. This can be seen in the north east of the study area where we had a lot of towns and other human settlements coming up

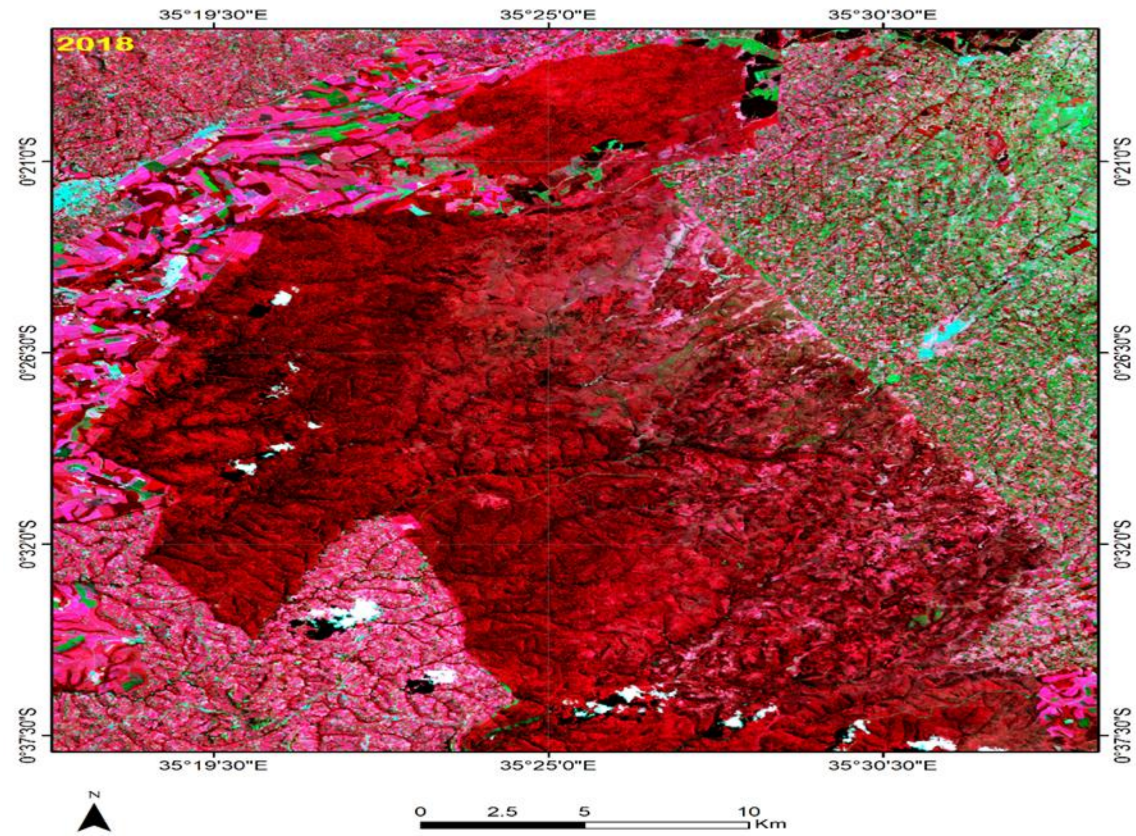


Figure 6: Increased cover in the year 2018 in the study area

Land cover has been increasing in the area since 2008 due to a lot of campaigns on environmental conservation and protection of water catchments, which have seen a lot of tree planting. The formation of the water towers agency and Mau task force has also improved on forest protection in Mau.

The blue color on the map image represents built – up area. There is also a clear mark of forest boundary and other features are clearer due to the improved technology on satellite imageries now compared to the 1990's

4.1.2 Comparison of the forest covers change between the result of Satellite imagery and the household surveys.

This was very important to assess the community perception and views on how they think the forest cover has changed. This was made to be compared with the results from forest cover change analysis. And whether it has affected the climate of the area. The respondents confirmed the changes which have resulted in destruction of crops especially if it is during maturity period of the crops like maize and beans. With intense rains, more erosion takes place leading to runoffs and less water infiltration.

The results corroborate with the global climate models which predict shifts variability and shifting in rainy seasons.

Table 4: Response on forest cover change from respondents in the study area

Change Rate of forest cover	No of respondents	Percentage
Drastic reduction in Forest cover	79	47.3
Much reduced	54	32.3
Little reduction in Forest cover	25	15.0
No change	9	5.4
Total	167	100

From the surveys, 133(79.9 %) of the total respondents responded that forest cover has changed in size over last 30 years and this is as a result of illegal poaching, human encroachment and this has affected the climate of the area.

This is through their experiences of the way the forest is used. The responses from respondents concur with studies of impacts of forest cover changes (Hesslerova and Pokorny 2011), which showed that the forest cover in Mau Forest has caused a decline in the level of precipitation of the affected regions. This they responded that it has impacted on the change of the weather seasons, thus affecting their food production. This concurs with the produced maps showing forest cover change over the years.

Drastic change - 50% Reduction in forest cover.

Much reduced -40 % Reduction.

Little Reduction - 30% Reduction in cover.

See figure .7

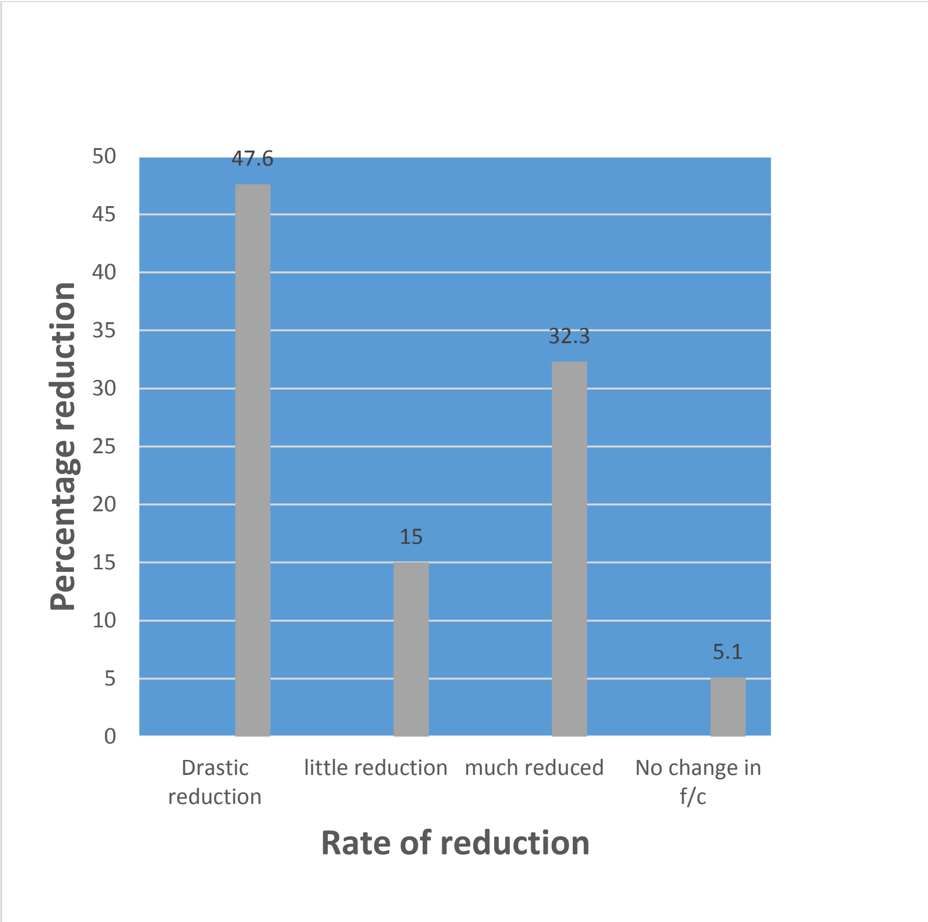


Figure 7: Response on the rate of forest cover change over some years. (Source, Field data, 2018).

4.1.3 Main causes of Deforestation

This was made to assess the main causes of deforestation to check whether it was for agricultural expansion as this could mean increased land for agriculture which might mean more food production. It was meant to give guidance when giving recommendations on the research in terms of control of deforestation.

Table 5: Respondents on causes of deforestation in the study area

Main activities	No of respondents	Percentage of respondents
Population growth	31	18.6
Illegal logging	65	38.9
Charcoal burning	44	26.3
Agriculture expansion	17	10.2
Infrastructure development	7	4.2
Others	3	1.8
Total	167	100

From the respondents, the main causes of deforestation in the study area is illegal logging, charcoal burning and population with a total percentage of (140) 83.8 %, while agriculture expansion, infrastructure development and others were the least cause with a percent of 27 (16.2 %).This showed that the community was aware of the causes of reduction of forest cover in their forest.

Although agricultural expansion was also a cause of deforestation, it was not a major cause compared to the other three. The respondents also said that if no action is taken on illegal logging and charcoal burning in the area; it will lead to more deforestation and thus so much environmental degradation in the area. The study of impacts of such land cover changes has shown illegal logging as being the major cause of reduction of forest.

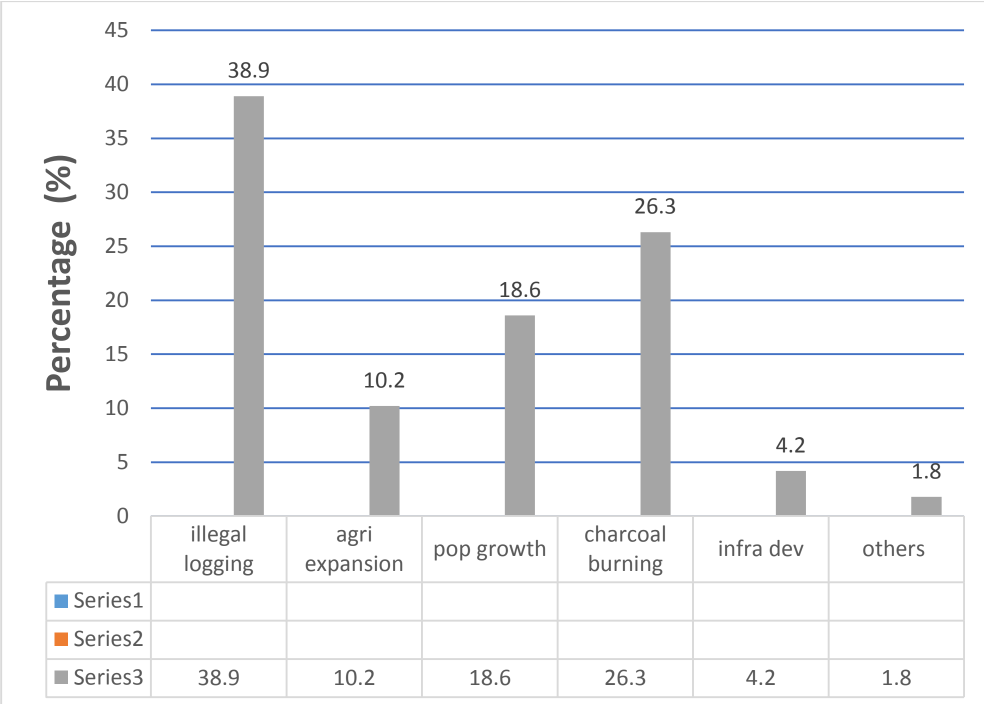


Figure 8: Response on the main causes of deforestation in the study area. (Source, Field data, 2018)

4.2.1 Rainfall trends:

The presentation of analysis of trend of the mean monthly temperatures showing the variations over season's .There are variations in observed rainfall trends over the years between 1987-2017.

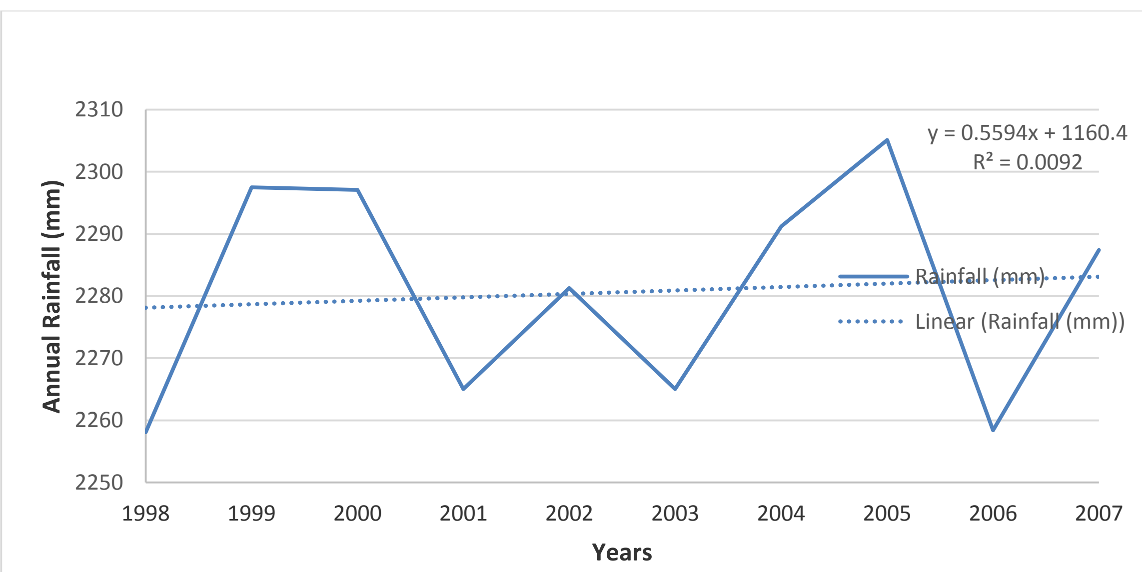


Figure 9: Time Series of mean Annual of rainfall between the years 1998 and 2007.

The change presents a positive gradient of 0.5594 and a correlation coefficient R^2 of 0.0092. R^2 represents the independent variable (years) in relation to dependent variables (annual rainfall). A positive gradient was observed in annual rainfall values. The rainfall amounts have varied over the years.

The rainy seasons between 1998 and 2007 revealed that the area received variable rainfall. It is apparent of the consistent variation of rainfall trends over time indicating yearly rainfall unpredictability. On the same the respondents affirmed that was affirmed by the farmers by confirming reduced crop yields.

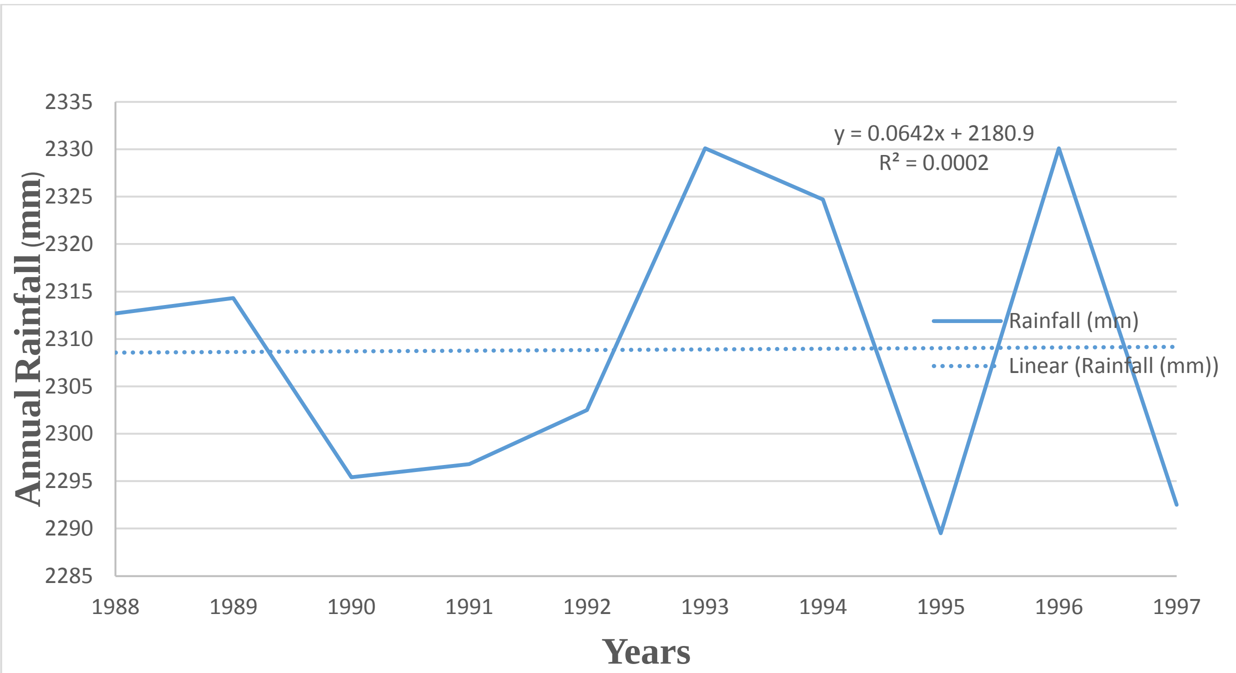


Figure 10: Time series of mean Annual rainfall between the years 1988 and 1997 in the five weather stations.

The Figure shows a positive gradient of 0.0642 with correlation coefficient of 0.0002 for the period between 1988 and 1997 for the stations.

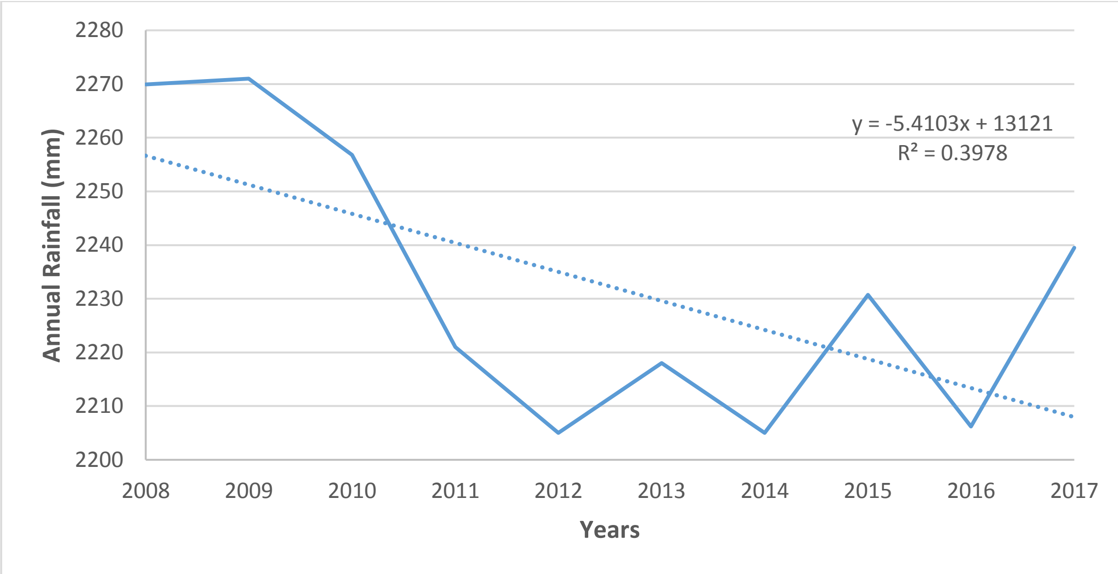
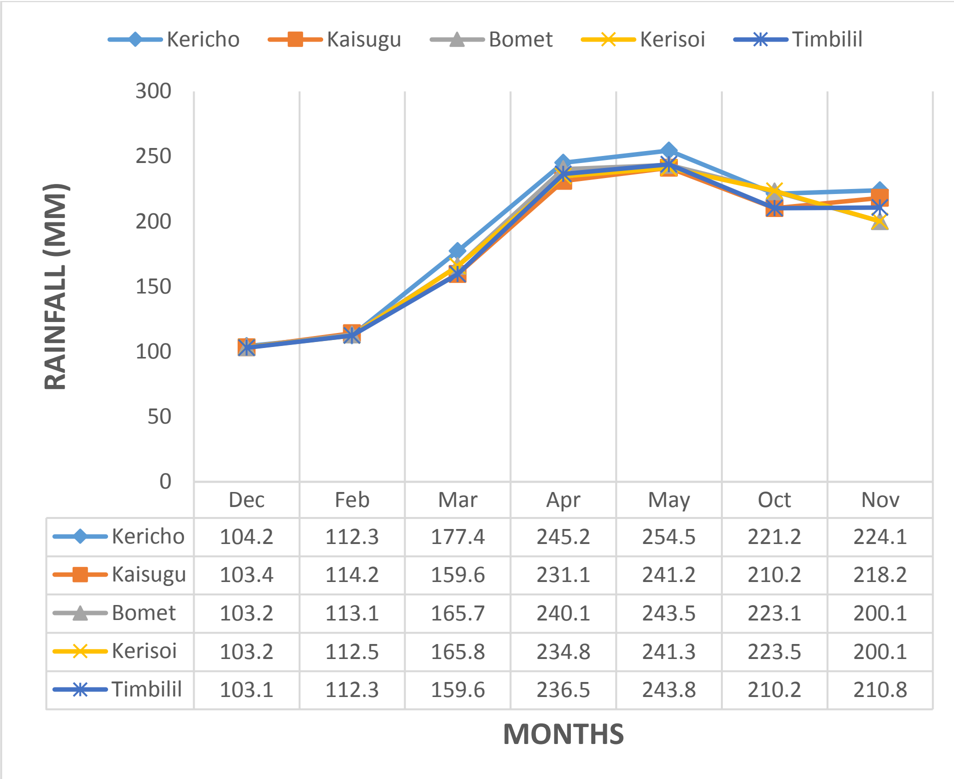


Figure 11: Graphical Plot of mean annual rainfall between the years 2008 and 2017 in the five stations

The trends show increased variation both in timing and the amount of rainfall over the period of ten years, a clear indication of climate change. A negative gradient (-5.4103) is observed in rainfall trend over the years from 2008 to 2017 for the five stations. Rainfall variability and reduced amount is observed compared to the previous years.

This shows rainfall variation. Month with highest rainfall with peak being in May. Kericho station had the highest amount of rainfall among the five stations followed by Bomet. The variation of rainfall amount in the five stations is minimal.

This also shows that March, April and May (MAM) are the long rains in the area where much rains are experienced. The period between December, January and February is the driest compared to the other months. The study area displays a bimodal rainfall pattern with high rainfall seasons. Highest amount of rainfall recorded was 245.5 in month of May in Kericho station. Similarly, the months of March, April and May were observed to record the highest amount of rainfall for majority of the stations over the study area.



	Dec	Feb	Mar	Apr	May	Oct	Nov
Kericho	104.2	112.3	177.4	245.2	254.5	221.2	224.1
Kaisugu	103.4	114.2	159.6	231.1	241.2	210.2	218.2
Bomet	103.2	113.1	165.7	240.1	243.5	223.1	200.1
Kerisoi	103.2	112.5	165.8	234.8	241.3	223.5	200.1
Timbilil	103.1	112.3	159.6	236.5	243.8	210.2	210.8

Figure 12: Trends of observed seasonal rainfall in the five selected weather stations around the Study Area

The figure shows that rainfall patterns with the main rainfall season is in the months of March, April and May (MAM) followed by the short rains in September, October and November (SON) with maximum rainfall being 254.5 mm for the month of May in Kericho and minimum being 103.1 mm for the December in Timbilil station. Data from all the stations were analyzed to check the rainfall trends in the study area.

It is apparent from observations that there was a reduction in amount of rainfall trend observed over time in the study area indicating rainfall unpredictability. (IPCC, 2014).It is observed that in the year 1980's, the study area was receiving some substantial amount of rainfall compared to the subsequent years of 2017's and that the rainfall has been reduced as years go by. This has led to unpredictable rainfall seasons which have in turn affected the food production in the area

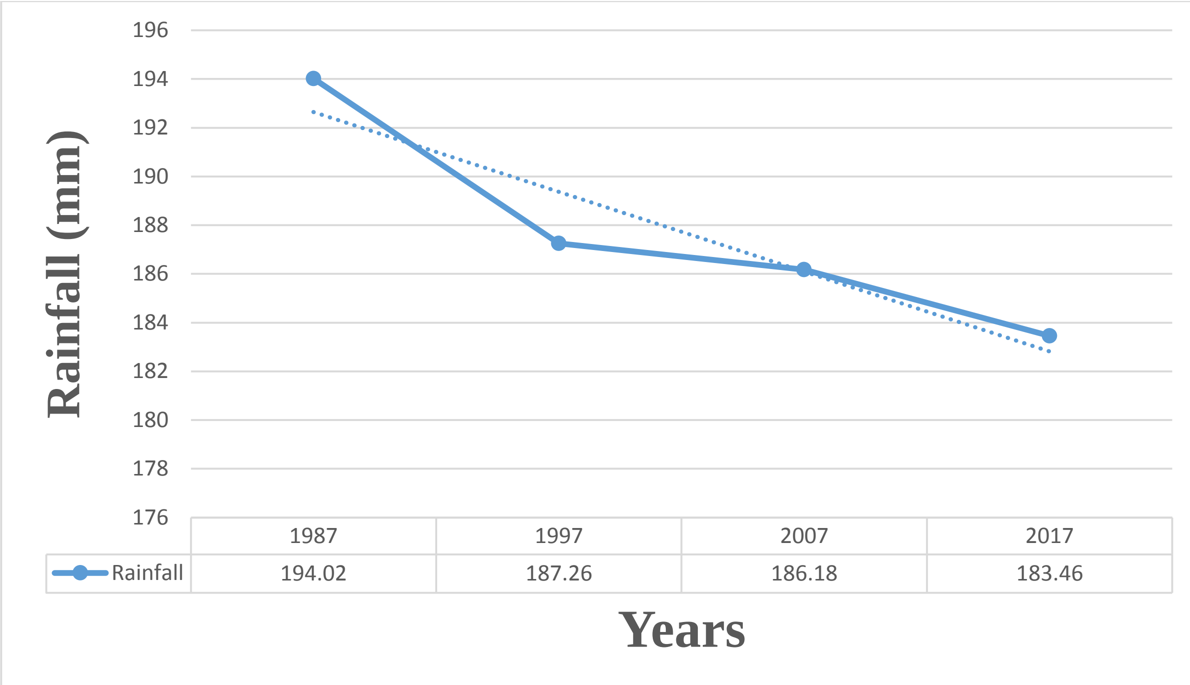
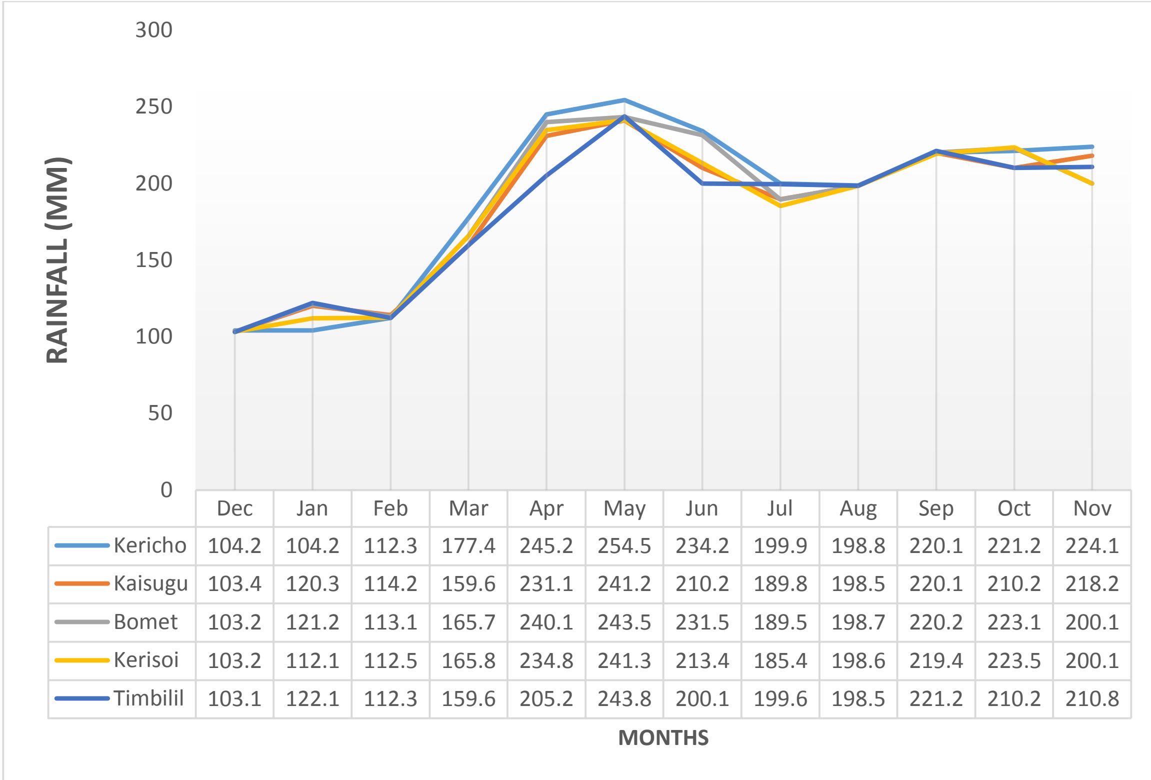


Figure 13: Mean annual rainfall trend for the last 30 years in the five selected stations.

The rainfall has decreased over the years.



	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Kericho	104.2	104.2	112.3	177.4	245.2	254.5	234.2	199.9	198.8	220.1	221.2	224.1
Kaisugu	103.4	120.3	114.2	159.6	231.1	241.2	210.2	189.8	198.5	220.1	210.2	218.2
Bomet	103.2	121.2	113.1	165.7	240.1	243.5	231.5	189.5	198.7	220.2	223.1	200.1
Kerisoi	103.2	112.1	112.5	165.8	234.8	241.3	213.4	185.4	198.6	219.4	223.5	200.1
Timbilil	103.1	122.1	112.3	159.6	205.2	243.8	200.1	199.6	198.5	221.2	210.2	210.8

Figure 14: Mean annual observed rainfall in the five selected stations

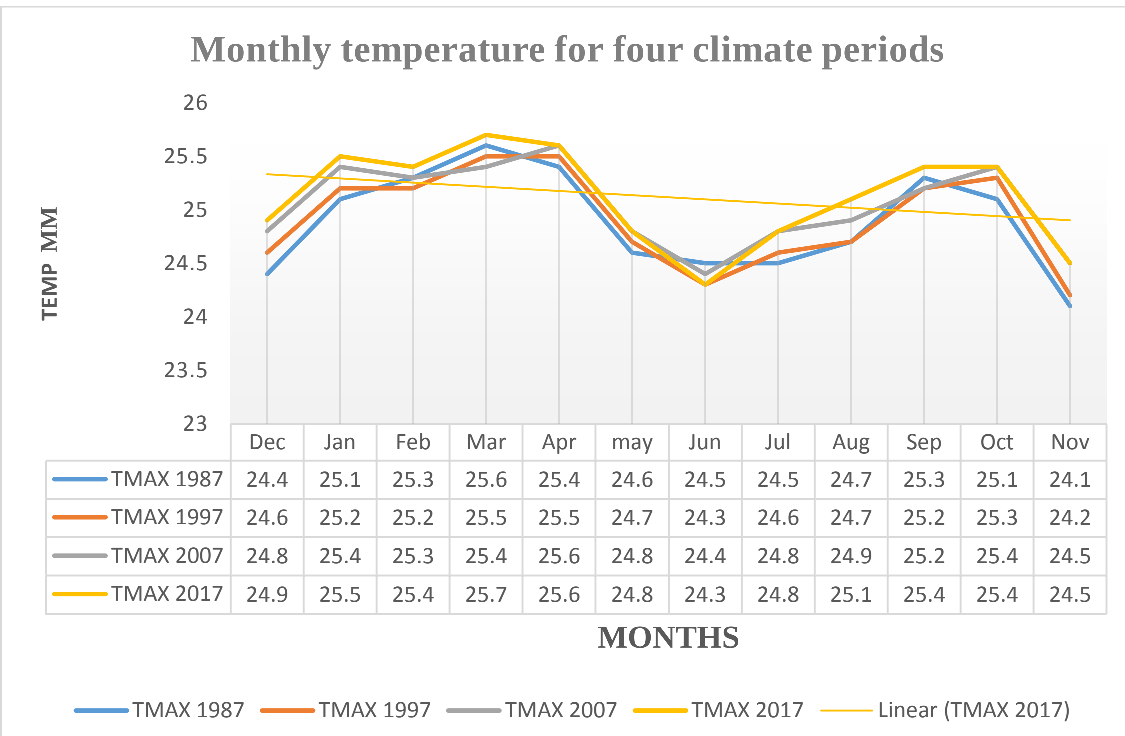
4.2.2 Maximum Temperature

The temperature range of 2.0^{0}C demonstrated that a significant rise in the temperature occurred between 1987 and 2017 and this concurs with the recent reports on the on heating (IPCC, 2012). The maximum temperatures vary from about 24.1$^0{}_C$ in June to 26^{0}C in end of March. It was noted that Maximum temperatures have progressively been increasing since 1980's. Temperatures in late 2016 are higher than those of 1990's which are in turn higher than those of 1980's.These changes are a signs of climate variation as indicated by increased temperatures day and night, temperatures are becoming warmer in the current climate compared to 1980's.

From the analysis of the patterns and trends of temperature, it shows that they have been increasing since 1980's to date and still continue warming. The rise in temperatures as seen from the graph shows that from 1987 through to 2017, the temperatures have been rising (IPCC, 2007). The findings by Omondi et al., (2014) found out that temperatures in Kenya are generally increasing and this is confirmed by the results of the four climate periods which shows temperature rise between the year 1987 and 2017. This observation concurs with the previous studies on temperature variability trend anomalies in the highlands.as done by king'uyu et al., (2000),Anyah and Semazzi(2006) on temperature variability trend anomalies in the highlands.

The lowest temperatures have occurred in the months of May, June and July, while the month of March has the highest rise in temperature.

This rise in temperature coupled with decreasing precipitation trends would result into reduced water supply which effects crop growth. Trends of increasing temperature and decreasing amounts of rainfall are in line with depicted trends in the reduction in farm yields in a farm. 2017 had the highest rise in temperatures indicating that there is rise in temperatures and are predicted to increase. The increased temperatures are noted to have reduced the farmer's farm incomes due to negative effects on crop production (Hererro et al., 2010).



	Dec	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov
TMAX 1987	24.4	25.1	25.3	25.6	25.4	24.6	24.5	24.5	24.7	25.3	25.1	24.1
TMAX 1997	24.6	25.2	25.2	25.5	25.5	24.7	24.3	24.6	24.7	25.2	25.3	24.2
TMAX 2007	24.8	25.4	25.3	25.4	25.6	24.8	24.4	24.8	24.9	25.2	25.4	24.5
TMAX 2017	24.9	25.5	25.4	25.7	25.6	24.8	24.3	24.8	25.1	25.4	25.4	24.5

Figure 15: Trends in Monthly Maximum Temperature for four climate periods in the stations around the Study Area (Source, Meteorological Data, 2018).

Max temp have increased over the years from 1987 – 2017, an indication of climate change.

The results for the temperature trends in the five stations show that the temperatures are rising (IPCC, 2014).

4.2.3 Minimum Temperatures.

The minimum temperatures vary from about 11^0C in August to about 12.3^0C in end of April. Lowest temperatures recorded over the months of July, august and September, while the minimum temperature has occurred months of March, April and May.

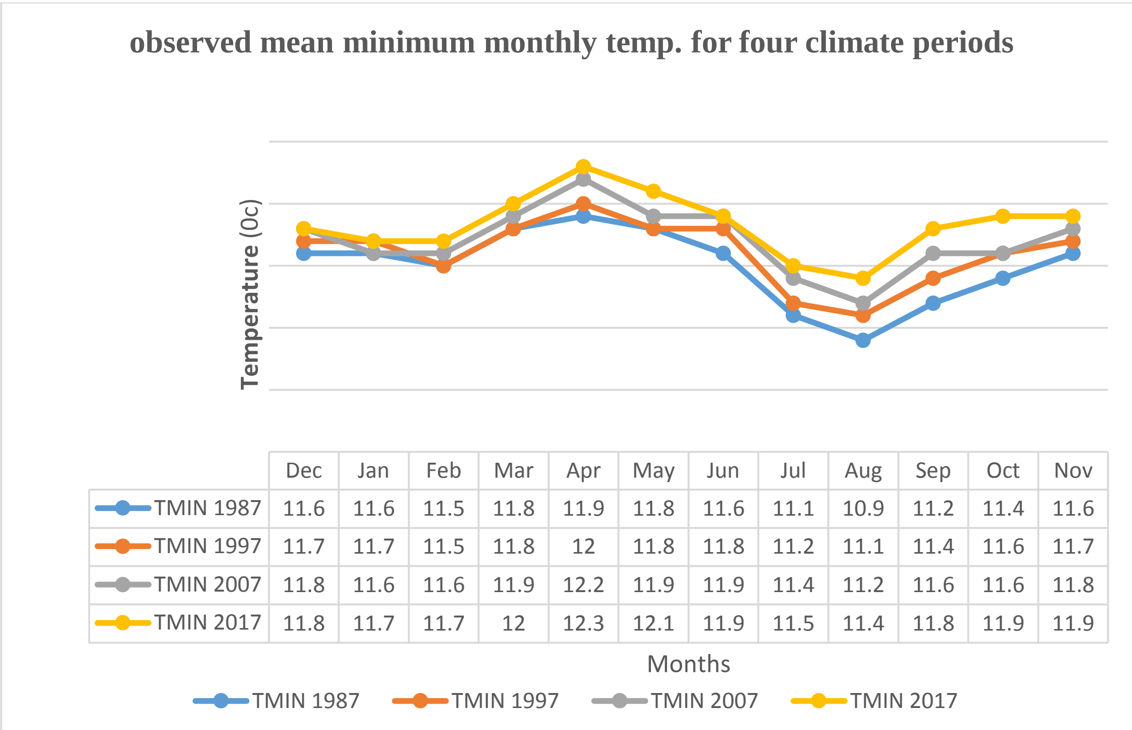


Figure 16: Observed Minimum monthly temperatures for the four climate period for Jericho Station (Source, Kenya Meteorological Department 2018).

4.3 General information on the sampled population

The study targeted a sample size of 165, including 10 key informants from 4 forest stations in the Mau Forest. A total of 165 respondents, 90 women and 75 men, filled in and returned the questionnaires.

4.3.1 Category of the respondent by gender.

Majority of the respondents involved in farming are usually women, men go to look for jobs and so this affects food production. For the social economic surveys, gender is very critical and is mostly used for surveys in households. The controller of household is the head of the family as he controls economic, land issue, income and expenditure.

Gender is an important socio-economic, cultural and demographic factor. Gender factor is important because it is men who mostly owned land in the area and so both should be involved in farming as this affects land utilization. Majority of the respondents were women 96.5(58.5%) and the rest were men 68.5(41.5%) of the respondents, thus the outcome of the study did not suffer any bias.

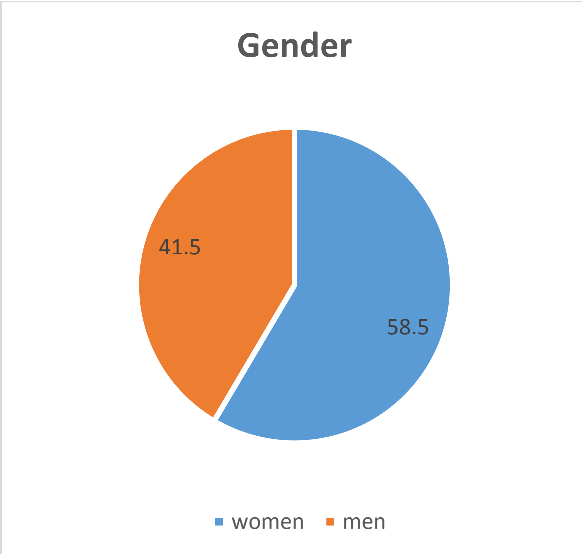


Figure 17: Respondents in terms of gender (Source, Field data, 2018).

4.3.2 Respondents distribution by of age

Age of respondents was sought in his study and the results tabulated according to gender.157 (93.9%) of the respondents had 35 of age, while minorities were below 34(6.1%) years of age as shown below. This also shows that the aged are the ones mostly involved in agriculture, while the young are not mostly engaged in farming activities.

Age factor is important in this study since the aged respondents have been able to see the change in in land use over time they have lived there as a result of clearance of forest thus affecting the climatic conditions of the area. This also correlates with the experience the farmers have in line with the change in forest cover. The ages and gender are evenly distributed showing that men and women are both involved in farming, but as age progresses, majority engage in farming. This also correlates with the experience the farmers have in line with the change in forest cover. The ages and gender are evenly distributed showing that men and women are both involved in farming and as age progresses, majority engage in farming

Table 6: Respondents grouped in terms of age

Age group	No of people	Percent (%)
18- 34	10	6.1
35-39	30	18.2
40-44	21	12.7
45-49	52	30.9
50 & above	54	32.1
Total	167	100

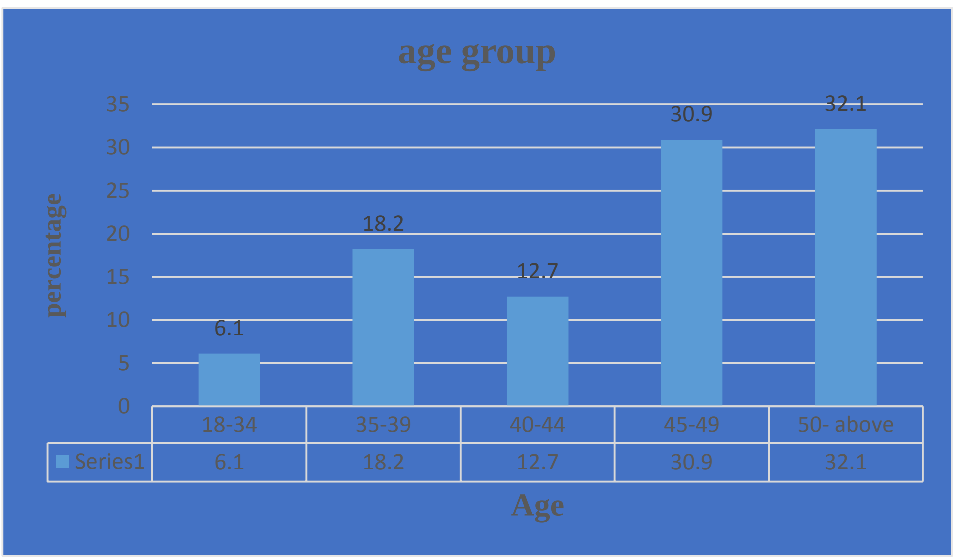


Figure 18: Respondents according to age group (Source, field data, 2018)

4.3.4 Experience in Mixed farming in the area

The number of years is important in assessing the experience of farmers, how change in rainfall patterns as years go by has affected their food production and the trend of production whether increasing or decreasing crop yields in both locations. This is also an indication that the farmers have lived there for some time to be able to experience change in soil productivity as soil erosion as a result of runoff, hence affecting crop production. This was an important factor in determining the change in food yields per acre and whether it was increasing on reducing over the years.

4.3.5 Main factors affecting food production in the area

This was a very important variable to assess as it was one of the objectives of the study. It was clearly explained to the respondents on how their experience in farming has been.

Table 7: The main factors affecting crop production in the area over years

Factor	No of respondents	Percentage
Unpredictable weather	54	32.7
Drought (high temp)	47	27.3
Soil erosion/runoff	35	21.3
Soil fertility	19	11.5
Others	12	7.2
Total	167	100

This was made to assess factors affecting food production in the area and link it with deforestation and climate change. From the results of the respondents from the two locations, it shows that droughts, unpredictable weather conditions and soil erosion are the main causes of poor crop production in the area with a percentage of 81.3 %.

Majority were also aware that forest clearance in the area attributed to incidents of droughts and unpredictable rain seasons. They had experienced low crop yields in the recent years compared to the last 5 years due to unpredictable rainfall which has adversely affected of food production.

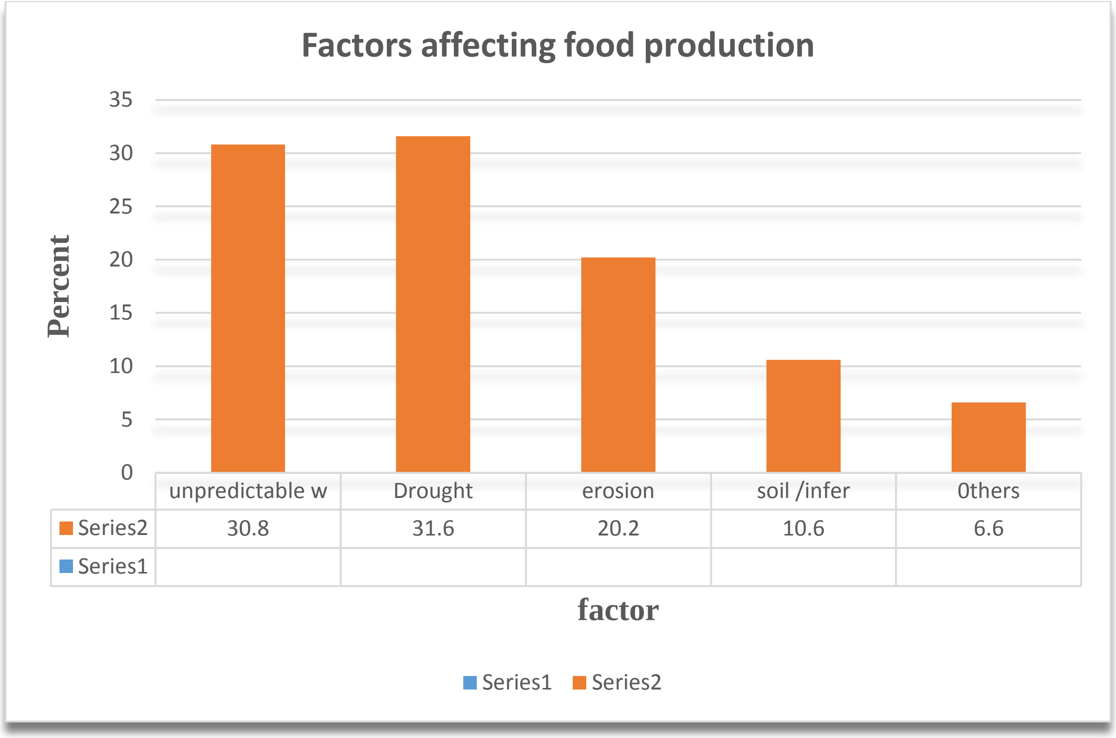


Figure 19: Factors affecting food production in the area. (Source, Field Data, 2018).

4.3.6 Rate of runoff occurrence

Aimed at assessing their view on the rate of soil erosion and how it has affected soil fertility in their farms. It was critical to assess its occurrence since it mainly affects farming in the area._This was very important as it was compared with the factors affecting food production in the area. From the table, 117.5(65.8%) of the respondents have observed an increased rate of soil erosion in the past years which has led to reduction in soil fertility, thus leading to reduced crop production. There has been variability of rainfall seasons accelerates soil erosion (Kotir, 2011) impacting negatively of livelihoods. The respondents added that soil erosion has been accelerated by the tree cutting activities taking place in the forest. Due to open ground upstream, the top soil is carried away downstream leading to soil degradation and reduction in soil fertility over past years.

Table 8: Perception on the rate of soil erosion in the past 20 years

Rate of occurrence	No of respondents	Percentage
Drastically increased	72	43.3
Much increased	45	25.5
Little increase	30	17.7
No change	16	9.8
Not sure	4	2.2
Total	167	100

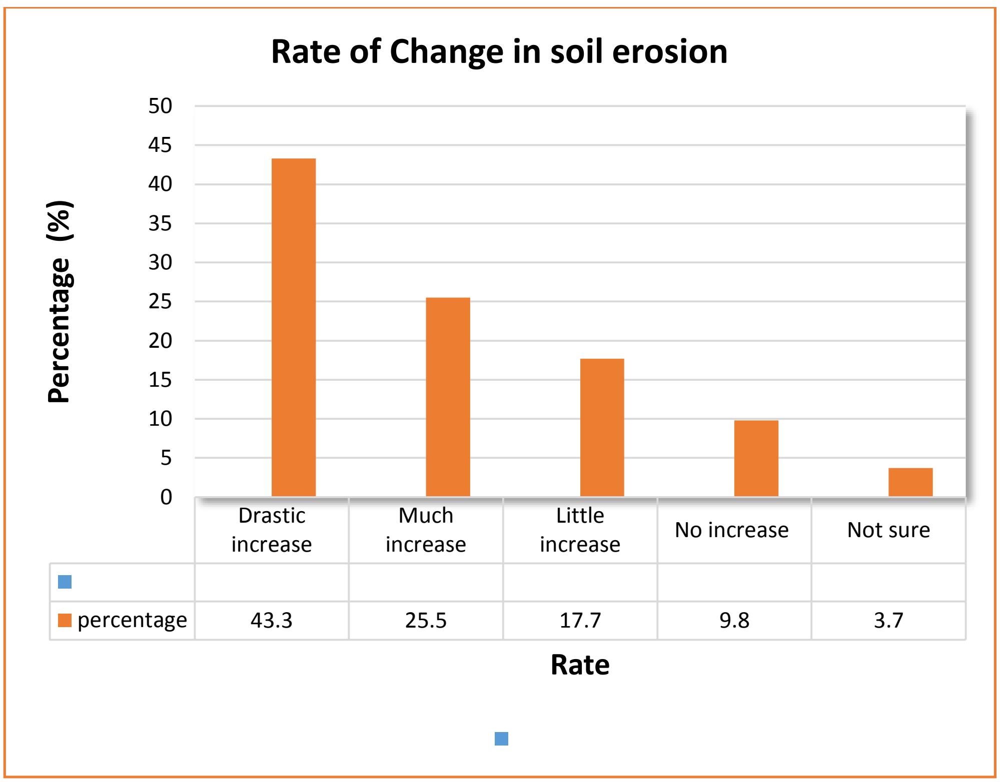


Figure 20: Response on the rate of soil erosion (Source, Field Data, 2018)

Table 9: Views on the effect of variability of weather seasons

Effects	Respondents	Percentage
Greatly affected	85	51.2
Slightly affected	54	32.8
Not affected	26	15.0
Not sure	2	1.0
Total	167	100

Information on how communities perceive climate change could lead to a better understanding of possible interventions that suit farmers' needs and support to adopt and mitigate against it. Majority of respondents (85%) who perceived climate change indicated that it has led to low crop yields, food insecurity and decline in crop productivity.

Majority of the respondents said that climate change and variability had greatly affected food production due to unpredictable rainfall patterns leading to unreliable rains and droughts. (IPCC 2007).

The respondents concurred that in the 1980's and 1990's rainfall were more irregular and temperatures have continued to rise. Rainfall has reduced in both quantity (amount) and patterns significant affecting crop yield (Kotir 2011). Temperatures were also noted to have increased, increasing the vulnerability of the farmers to the effects of climate change. (Hererro *et al*., 2010). Many communities believe that change of seasons has occurred in the area and only a small percentage reported of not experiencing climate variability. This study is comparable to elsewhere in Africa where farmers have been adversely affected (Mengistu, *et al*., 2011). It was noted from the respondents that generally climate change has over the years affected food production in the area leading to negative effects on farm yields production.

Shifting in thermal rainfall regimes which affect local seasonal and annual water balances affecting the distribution of rainfall and temperature thus affecting moisture build-up in the soils (Herrero *et al*., 2010) as Kenya mainly relies on Rain-fed agriculture (Fischer *et al*., 2002; Comprehensive

Assessment, 2007). According to (Kabara and Kabubo-Mariara, 2012). Farm production has been adversely affected by climate change. Just like any other African countries.

Much transpiration from the crop during the growing season will mostly occur in many areas with alternating wet and dry season, where the annual rainfall will be less than the amount of water that a crop well supplied with water will lose. (Ayanlade *et al*., 2010).

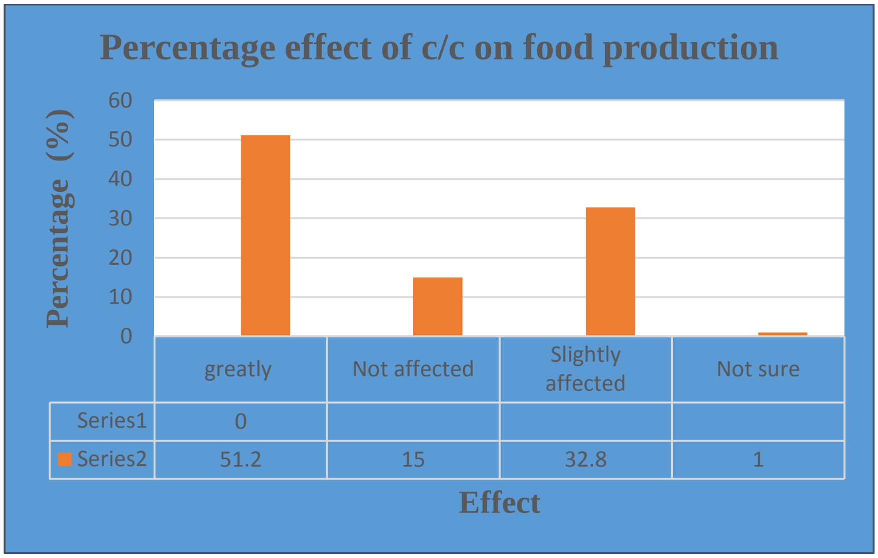


Figure 21: Respondents views. (Source, Field Data, 2018).

4.3.8 Respondents views on changes in crop yield over the years.

Farmers stressed that the declining crop production was due to low rainfall, incessant rains coupled with increasing temperatures. Their results concurs with those of (IPCC 2007) which predicted that by 2050, there will be deeper vulnerability due to poverty pushing the vast number of already poor who depend on agriculture as their main livelihood in the sub-Saharan Africa (Kabara and Kabubo – Mariara 2011).

Table 10: Reduction in yields in Maize and beans (bags) /acre for the last 20 years

No of bags/acre	No of respondents	Percentage
Reduced from 20-15	34	19.4
Reduced from 20-10	46	27.7
Reduced from 20-8	46	27.8
Reduced from 20-5	37	21.7
Reduced from 20-2	3	1.8
Not sure	1	0.7
Total	167	100

The responses were very critical to assess how food production has been over the years so as to analyze how the above factors have impacted on food production. The response shows a drastic reduction in Maize and Beans yields in terms of bags /acre. This was mainly attributed to drought and unpredictable weather conditions in the area.

Table 11: Reduction in food production/acre.

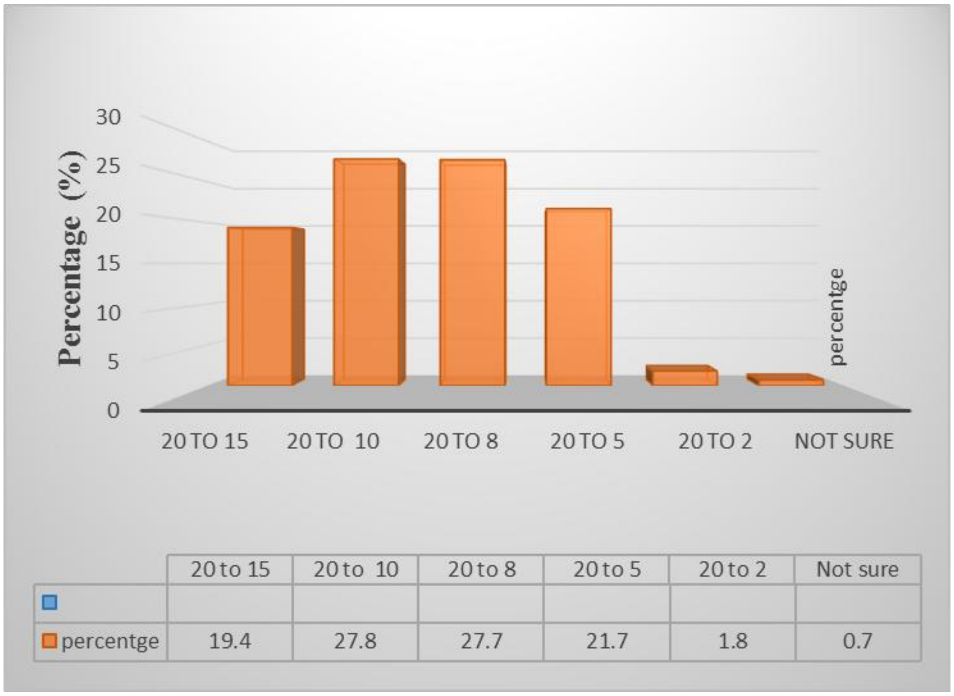


Figure 22: Reduction in the number of bags per acre over some period. (Source, Field, Data 2018)

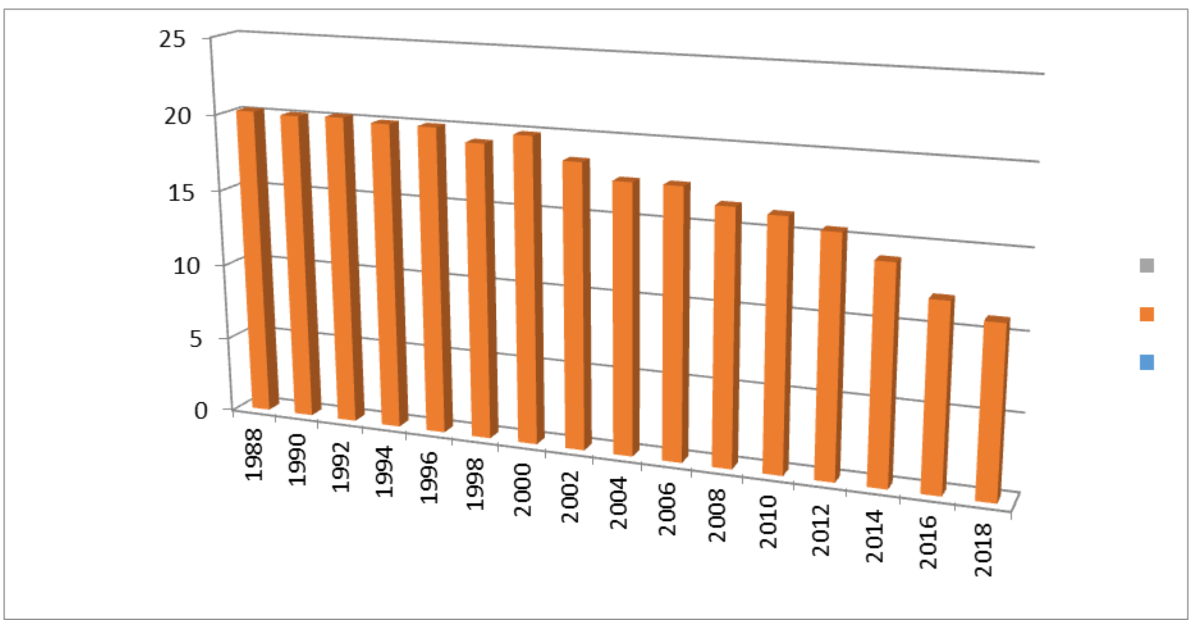


Figure 23: showing the average no of bags produced per acre in the area data (source agriculture office kericho.)

Table 13 : Forest cover versus mean annual rainfall.

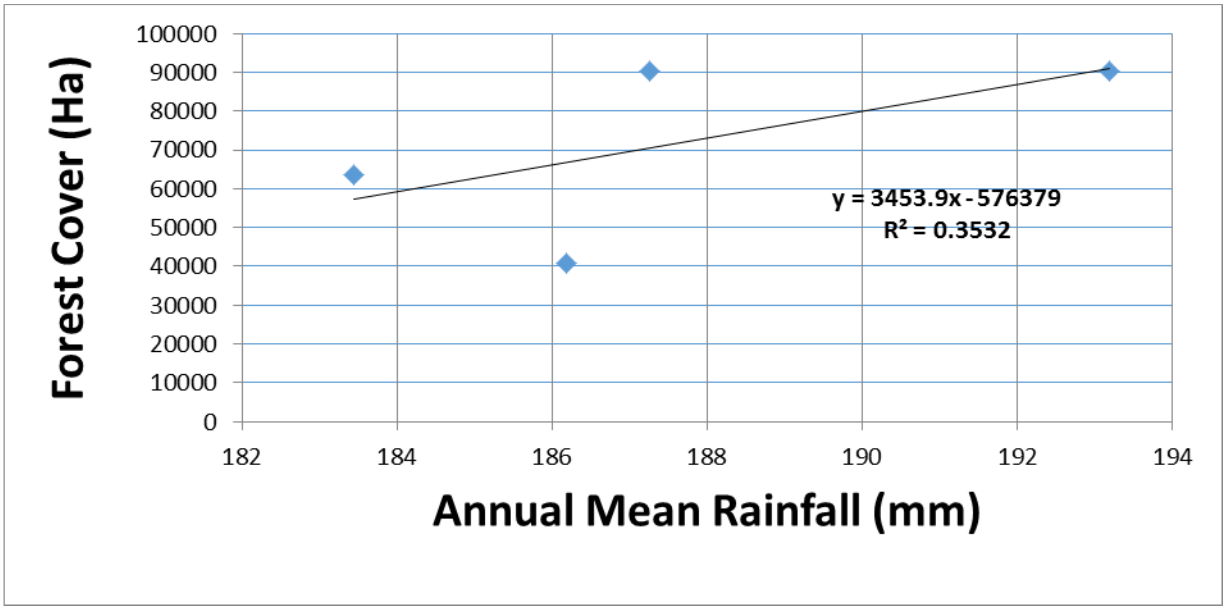


Figure 24: Scatter plot of rainfall and Forest cover change.

The change in rainfall is positively related to change in forest cover, meaning a reduction in forest cover has led to reduced amount and variability of rainfall. This is because forest cover has an influence on the hydrological cycle and the convection ,thus affecting condensation and cloud formation Annual mean rainfall is highly and positively related to the forest cover with a correlation coefficient of 0.594.This also correlates with the calculated correlation coefficient which is 0.5943,an indication of a moderately high positive relationship. The line of best fit is an output of regression analysis

Table 14: Forest cover versus annual maximum temperature.

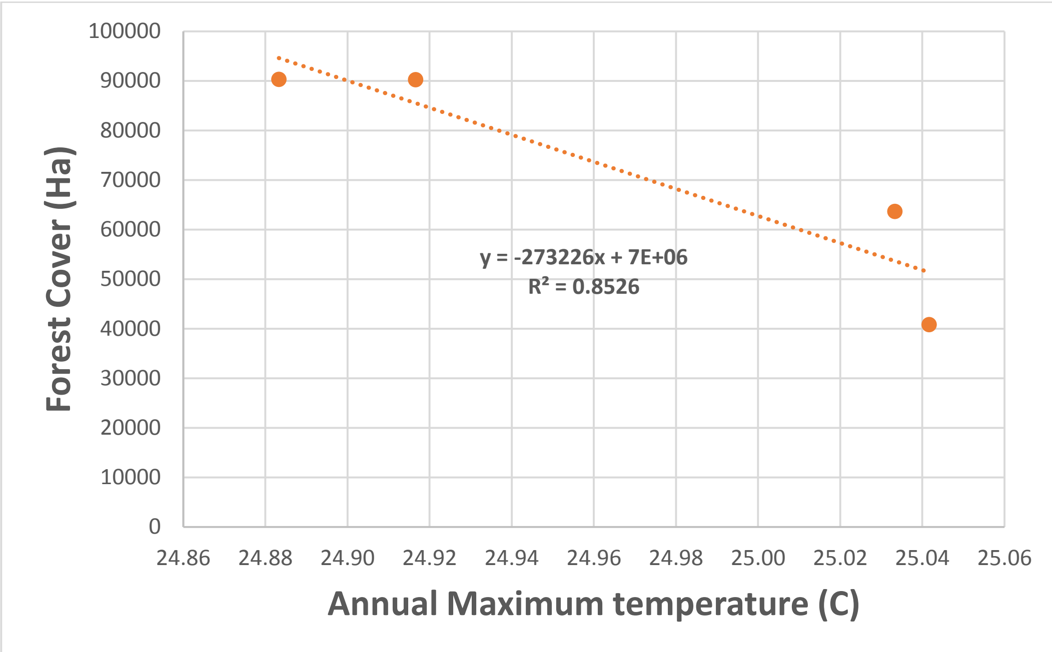


Figure 25: A scatter graph of Forest cover and annual maximum temperature (Source KMD)

For temperature, the forest cover change is negatively correlated to annual maximum temperature with a coefficient of -92.3, meaning that as the forest cover reduces, the annual maximum temperature increases significantly. Meaning that there is no correlation between annual maximum temperature and forest cover change

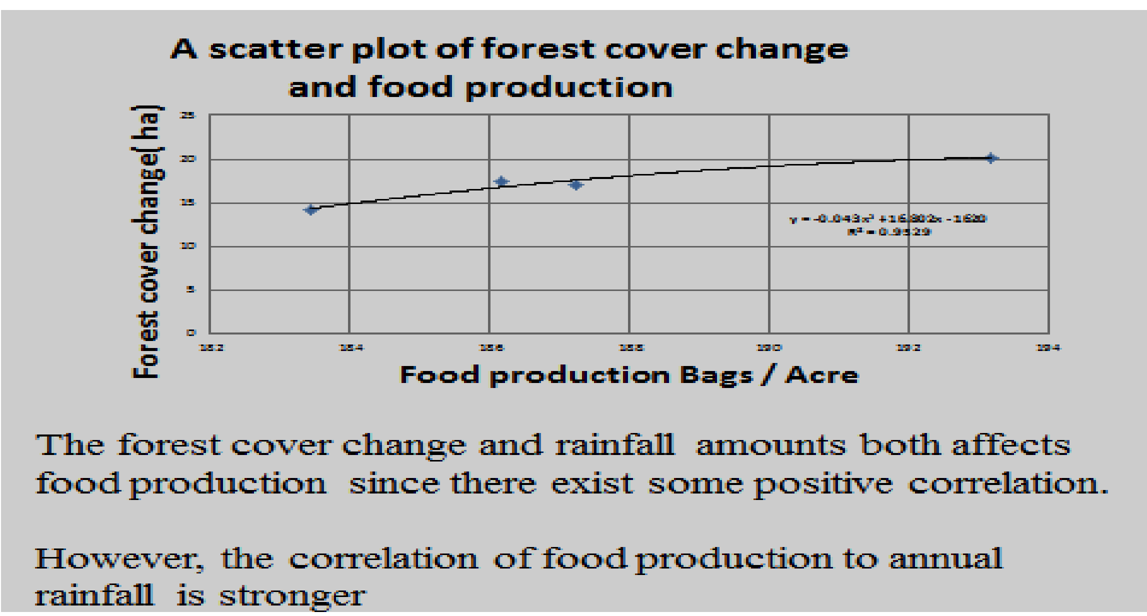


Table 26: The relationship of forest cover change versus food production

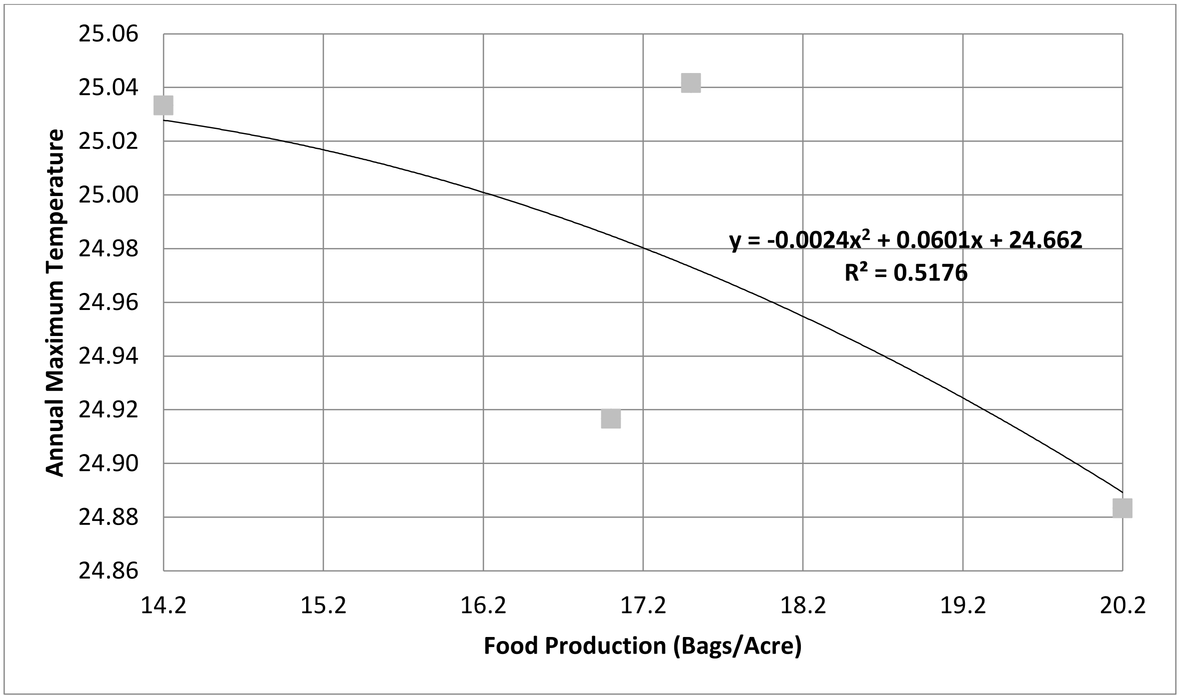


Figure 26: A scatter plot of correlation between food production and maximum annual temperature.

From the above graph, increase in the maximum annual temperature has led to decreasing food production in hectares. The increasing temperatures led to sun scotching of the crops. At 25.03 0c, the food production is 14.2 bags /acre while at 24.86 0c; the food production is 20.2 bags /acre, an indication of food production and vice versa

CHAPTER FIVE

5.0 Summary, Conclusion and Recommendation

5.1 Summary.

Landsat images for four different epochs for 1988, 1998, 2008 and 2018 was undertaken with a spatial resolution of 30 meters and thereafter, a comparative analysis done to assess the forest cover change.(FCC). The study demonstrated much land cover change due to illegal logging. Deforestation has therefore led to climate change and decreased soil fertility due to surface runoff and reduced natural water seepage.

It was observed that forest cover change drastically occurred in the years between 1998 and 2008 of 54.7 due to illegal settlements logging and population increase. The rates of forest cover change due to deforestation have been on the rise. Deforestation driven by various causes like logging and increased population which had negative effects. This has impacted on climate change causing climate variability and change of weather seasons which has in turn affected food production in the area.

From this study the distribution of precipitation and temperature shows temporal and spatial variations, the results shows that the rainfall amounts have decreased gradually over the catchment and the temperatures have been significantly increasing too. The events related to climate change are mostly related to extremes like drought, floods leading to low rainfall density, increased warming and unpredictable weather patterns. The findings concurs with Haile's (2007) research findings that rainfall variability results to significant negative effects on the growth of crops.

From the results, the extremes of drought and floods have affected the crop yields and will continue in the future. Rising temperatures due to climate variability and reduced amount of rainfall have led to depicted trends of reduced food production. Increased temperature coupled with reduced precipitation trends have resulted to reduced food and farm yields

From the study, food production has reduced in the area as a result of negative impacts of Deforestation weather seasons, thus impacting on water hydrological cycles and soil fertility in the area. Climate variables are positively related to food production; hence food production over the study area has been negatively affected by these changes as shown by increasing rates of deforestation, from this study the distribution of precipitation and temperature shows temporal and spatial variations.

5.2 Conclusion

(1) The results provides information that can be used to develop the policy options that are so urgently needed by decision makers in the country on deforestation and climate and to sustainably manage precious natural resources .

(2) From the results of the study, the policy makers and communities are well informed about the importance of forest conservation and climate change mitigation measures for improved food production for better incomes and improvement of community livelihoods

This will create awareness to the various stakeholders on the negative effects of deforestation, its effects farm yields.

(3) This study helps policy makers to achieve the goals, thus a basis for implementing development and provide information on deforestation in the context of its impact on food security creates ,thus bridging the gap to policy makers and supportive development agencies who should contribute to forest conservation, hence creating conducive environment for agricultural production systems.

(4) The study provides findings to guide conservationists, the government to curbing deforestation by involving other stakeholders and formulating policies to mitigate to climate change and improving rural livelihoods of the communities living here and the country at large.

(5) The findings from this study provides useful information to inform long and short term planning and conservation of natural resources for improved food production and community livelihoods..

(6) The results indicate deforestation has negative implications on food production and so efforts should be made to conserve this critical resource.

(7) The findings informs policy makers on formulating and enacting laws, policies and regulations with full stakeholder involvement and strict implementation of the same for sustainable forest resource conservation and management. The government should by way of strict laws and regulations preserve forest reserves by preventing all causes of deforestation.

Deforestation is a main contributor to increased concentrations of the atmospheric (GHG, s) which causes significant changes in global climatic patterns which subsequently lead to global warming (IPCC, 2014). Deforestation affects climate system dynamics, atmospheric composition and other ecosystem processes.

5.3 Recommendations

(1) There is had urgent need for controlled deforestation as a way of militating against climate change.

(2) To ensure adequate food production it is recommended that efforts to rehabilitate the Forest Complex should be carried out.

(3) Enough food production and food security in a country can only be attained in a well conserved and sustainably managed natural resource and this should be carried out in Mau forest.

(4) The government, all stakeholders and communities must be involved in conservation of this natural resource base.

5.4 Limitations of the study

These included:

Other factors of food production like farm inputs which could affect food production.

Financial constraints which affected the scope of area to be covered.

References

Akotsi, E., & Gathanja, M. 2004. Changes in forest cover in Kenya's five water towers, 2000-2003.

Akotsi, E.F.N., Gachanja, M. and Ndirangu, J.K., 2006. ‗Changes in Forest Cover in Kenya‗s . Five ―Water Towers‖ 2003-2005‘. Kenya Forests Working Group and Department of Resource Surveys and Remote Sensing (Kenya) with support from the Royal Netherlands Embassy.

Arnold, J. E.M. 2001. Forests and people: 25 years of community Forestry. Food and Agriculture Organization of the United Nations, Italy, Rome.

Angelson, A. and Wunder, S. 2003. Exploring the forest-poverty link: key Concepts, issues and research implications. CIFOR Occasional Paper No. 40, Centre For International Forestry Research, Bogor

Aina, A. T. and Salau, A. T. (1992). The challenges of Sustainable development in Nigeria. Nigerian Environmental Study/Action Team (NEST), Rio –De-Janeiro, Brazil, pp8-16.

Ayanlade, A., Odekunle, T.O. and Orimoogunje, O.O.I. (2010). Impacts of Climate Variability On Tuber Crops in Guinea Savanna Parts of Nigeria: A GIS Approach. Journal of Geography and Geology, 2(1):27 -35.

Ayuyo Isaac 2014. Landcover and Land use Mapping and change Detection of Mau Complex in . Kenya using Geospartial technology. Pp 201.

Anyah, R. O. and Semazzi, F.H.M. (2006). Climate variability over the Greater Horn of Africa Based on NCAR AGCM ensemble. Theoretical and Applied Climatology, 86 (39): 1-4.

Awuor, V.O, M. A. abira and J.S ogola (1997). Effects of Climate change on agriculture: Potential Impacts of climate change in Kenya. Climate network Africa. Nairobi, Kenya.

Baldyga, T. J., Miller, N. S., Driesse, L. K., & Gichaba, N. C. (2007). Assessing land cover. Change in Kenya's Mau Forest region using remotely sensed data. African Journal Of Ecology, 46: 46–54.

Balakrishna, P., and E. Warner (2003). 'Biodiversity and the Millennium Development Goals'. IUCN Regional Biodiversity Programmed, Asia. UNDP.

Bergkamp, G, Orlando, B .and Burto. 2003. Change adaptation of water resources Management to Climate change, Switzerland, World Conservation Union (IUCN).

Belcher, B., Ruiz-Perez, M. and Achdiawan .R. 2005. Global patterns and trends in the use And management of commercial NTFPs: implication: Implications for livelihoods And conservation World Development Vol Belcher, B., Ruiz-Perez, M. andAchdiawan

R. 2005. Global patterns and trends in the use and management of commercial NTFPs implication: Implications for livelihoods and conservation World Development Vol 33(9), Pp. 1435 - 1452.

Bradshaw C, (2007) Global evidence that deforestation amplifiers flood risks and severity in The Developing world. Global Change biology 13:2379-2395.

Bryman, Alan. 2008. Social Research Methods. New York: Oxford University Press.

Bruinzeel, L.A. (1996). Predicting the Hydrological Impacts of Land Cover Transformation in The Humid Tropics: The Need for Integrated Research in Amazon Deforestation.

Boitt, M.K. (2016) Impacts of Mau Forest Catchment on the Great Rift Valley Lakes

In Kenya, Journal of Geoscience and Environmental Protection, 4, Pg137-145.

Kenya. http://dx.doi.org/10.4236/gep.2016.45014

Cao, M, Zhang, Q. and sugar, H.H. (2001) .Dynamic responses of African ecosystem

Carbon cycling to climate change. Climate change research, 17:183-193.

Castillo C and Gurney K (2012).Exploring surface biophysical climate sensitivity to

Tropical Deforestation Rates using a GCM: feasibility study .Earth interactions

16:1-23.

Chand, B.M., Upadhyay, B.P., Maskey, R.2012.Biogas option for mitigating and adaptation

Of climate change.Rentech symposium Compendium, Volume 1 March

2012.

Chrispine, O.M. Mary, O.A & Mark B.K. (2016) Assessment of the Hydrological impacts of

Mau Forest Kenya Hydrol current Res 7: 223 doi: 10.4172/2157-7587.1000223

Ericksen, P., Thornton, P., Notenbaert, A., Cramer, L., Jones, P. and Herrero, M. (2011)

Mapping hotspots of climate change and food insecurity in the global tropics; CCA.S .
Report No. 5. 1904–9005; CGIAR Research Program on Climate Change, Agriculture . And Food
Security (CCAFS): Copenhagen, Denmark, pp. 1–29. FAO

DRSRS/KFWG (2006): Changes in forest cover in Kenya's Five Water Towers: 2003–2005;

A presentation by the Department of Resource Surveys and Remote sensing, and

Kenya forests Working Group with support from the Royal Netherlands Embassy

November 2006, 1-28.

FAO (2013), the State of Food Insecurity in the World 2013. The

Multiple Dimensions of Food Security. Rome, FAO. Food and Agricultural

FAO (2010). Global Forest Resources Assessment 2010. Main Report. FAO Forestry Paper.

Food and Agriculture Organization of the United Nations, Rome

FAO. (2009). Food and agriculture organization of the United food and Agriculture Organization .of the United Nations .Crop evapotranspiration: Guidelines for computing crop Water requirements- FAO irrigation and drainage paper 56, Rome, Italy.

FAO-UNESCO. (1988) Soil Map of the World, Revised Legend. FAO World Soil Resources Report

FAO (2007). The millennium Development goals: Road Ahead: New York: United Nations. Food and Agricultural Organization

FAO. (2004). the State of Food Insecurity in the World 2001. Rome pp. 4-7 Food and Nutrition Technical Assistance Project (FANTA). (April 15–16, 2004) Measuring Household Food insecurity.

FAO. (2002). the State of Food Insecurity in the World 2001. Rome pp. 4-7 Foods and Nutrition Technical Assistance Project (FANTA). (April 15–16, 2004) Measuring Household Food insecurity.

FAO. (1991). Rome Declaration on World Food Security And World Food Summit Plan Of Action. World Food Summit 13-17, November Rome. FAO, 1983.Report of the eighth session of the committee on world food secu Security.

Fischer, G., Shah, M. and van Velthuizen, H. (2002). Climate Change and Agricultural Vulnerability. Vienna: International Institute for Applied Systems Analysis (IIASA). Funk

Vink (2012). Declining global per capita agricultural production And warming oceans threaten food security. Food Security, 1(3), 271-289.

ROME13-20 April 1983, CL 83/10 ROME. Dimensions of FAO Online. Forestry. Towards sustainable Forest management

Galvin, K.A., Boone, R. B., Smith, N. M. and Lynn, S.J. (2001). Impacts of climate variability On East African pastoralists: Linking social science and remote sensing. Climate Research, 19: 161–172.

Gregory, P.J., Ingram, J.S.I. and Brklacich, M. 2010. Climate change and food security .PhilTrans. R.S Soc.B 360: 2139-2148

Gregory, P. J., Ingram, J. S. I. & M, B., 2005. Climate Change and Food Security Philosophical Transaction of the Royal Society, Issue 360, pp. 2139-2148.

GOK, (2010a): Rehabilitation of the Mau Forest Ecosystem Programme; Prepared by the Interim Co-coordinating Secretariat, Office of the Prime Minister, on Behave of The Government of Kenya, with Support from the United Nations Environment Programme, April 2010, 260

GoK. (2010). National Climate change Response Strategy: Executive Brief. Ministry of Environment and Mineral Resources. Government of Kenya (GoK), Nairobi.

GOK, 2009. Rehabilitation of the Mau Forest Ecosystem. A project Concept prepared by The Interim Coordinating Secretarial Office of the prime minister, on behalf of The government of Kenya September, 2009.

Haile, N. (2007). An Economic Analysis of Farmers' Risk Attitudes and Farm Households' Responses to Rainfall Risk in Tigray, Northern Ethiopia. PhD thesis, Mansholt Graduate School of Social Sciences, Wageninger University, the Netherlands.

Herrero, M., Ringler, C., van de Steeg, J.,Thornton, P., Zhu, T., Bryan, E., Omolo, A., Koo, J And Notenbaert, A. (2010). Climate Variability and Climate Change and their Impacts on Kenya's Agricultural Sector; International Livestock Research Institute (ILRI): Nairobi, Kenya.

Hesslerová, P., & Pokorný, J. (2011). Effect of Mau forest clear cut on temperature distribution And hydrology of catchment of Lakes Nakuru and Naivasha: preliminary study Water and Nutrient Management in Natural and Constructed Wetlands (pp. 263-273): Springer.

IPCC, (2007): Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon et al). Cambridge University Press, Cambridge, United Kingdom and New York, NY, 93-217

IPCC. (2012). Managing the risks of extreme events and disasters to advance climate change Adaptation. A special report of Working Groups I and II of the Intergovernmental . Panel on Climate Change. Cambridge, United Kingdom and New York, USA: Cambridge University Press. 582p. IPCC

IPCC. (2014). Summary for policymakers. In: ClmateChange2014: Impacts, adaptation, And vulnerability. Part A: Global and sectorial Aspects. Contribution of working Group II to the fifth assessment Report of the intergovernmental panel on Climate change [Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Biir, T.E, Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C.G., Girma, B., Kissel, E.S, Levy, A.N., MacCraken, S., Mastrandrea P.R.M. and White, L.L. (eds.)].Cambridge University Press, Cambridge, United Kingdom and Newyork, NY, USA, pp. 1-32

Kabara, M. and Kabubo-Mariara, J. (2011). Global Warming in the 21st Century: The Impact on Agricultural Production in Kenya. In J.M. Cossia (Ed.) Global Warming in the 21st Century. Chapter 8 (199-214). Nova Science Publishers, New York

Kabubo-Mariara, J., and F. Karanja, 2007. The Economic Impact of Climate Change on Kenyan Crop Agriculture: A Ricardian Approach. Global and Planetary Change 57: 319 -330

Kaimowltz, Byron, 1988 Deforestation led to diminished income and food generating capacity High rate of soil erosion and siltation of waterways, loss of species and increase in Carbon emissions leading to global warming

Kenya Forest Service (KFS) (2013). Report Ministry of Forestry and Wildlife, Analysis of Drivers and underlying causes of Forest cover change in the various forest types

In Kenya. July 2013: Nairobi Kenya

Kenya Forest Working Group. 2006. Changes in Forest cover in Kenya's five water Towers: 2003-2004. http://www.kenyaforests.org.

Kenya Wildlife Service (KWS) (2009). Report of the Prime Minister's Task Force on The Conservation of the Mau Forests Complex. March 2009: Nairobi, Kenya

Kiage, L. M., Liu, K. B., Walker, N. D., Lam, N. & Huh, O. K. 2007: Recent Land-cover/use change Associated with land Degradation in the Lake Baring catchment, Kenya, East Africa: evidence from Landsat TM And ETM+.International Journal of Remote Sensing 28, 4285-4309

Kinyanjui, J.M., (2009): The effect of human encroachment on the forest cover, composition And structure in the western blocks of the Mau forest complex, PhD thesis, Egerton University, Kenya, 128

Kinyanjui, M. J. (2012). NDVI-based vegetation monitoring in Mau Forest Complex, Kenya African. Journal of Ecology 49, 165–174.

King'uyu, S. M., Ogallo, L. A., and Anyamba, E. K. (2000). Recent trends of surface minimum . b and maximum temperatures over Eastern Africa. Journal Climate. 13(16): 2876-2885.

Kombo, Donald, K. and Delno, Tromp, L. A. 2006. Proposal and Thesis Writing: An Introduction. Nairobi: Paulines Publications Africa.

Kotir, J.H. (2011). Climate change and variability in Sub-Saharan Africa: A review of current . And future trends and impacts agriculture and food security. Environment . Development Sustainability, Pg. 13, 587–605.

KTWA, (2013): Rapid Assessment of the Mau forest water tower, a report of the Kenya Water Towers Agency (KWTA) detailing the status of the land cover, land Cover change and associated hydrological trends in the Mau forest water tower in The period 1990-2013, 51

Kundu, P. M. (2007). Application of remote sensing and GIS techniques to evaluate the impact of land use and land cover change on stream flows: The case for River Njoro Catchment in eastern Mau-Kenya. PhD Thesis. Egerton University, Kenya

Laurence, W.F., Laurance, S.G and Delamonica p (1998). Tropical forest fragmentation and Greenhouse gas emissions. Forest ecology and management.110; 173-180.

Lobell, D., Schlenker, W. and Costa-Roberts, J. (2011). Climate trends and global crop Production since 1980. Science, 33:616-620.

London. Cochrane AM Laurence FW (2008) Synergisms among fire, land use and climate Change in the Amazon, journal of environment 37:522-527.

Mendelsohn R, W. Nordhaus, and D. Shaw. 1994. The Impact of Global Warming on Agriculture: A Ricardian Analysis. American Economic Review 84: 753-771.

MEMR (2012) Master plan for the conservation and sustainable management of water catchment . Areas of Kenya. Ministry of environment and natural resources.

Melillo, J. M., Richmond, T. T. & Yohe, G. W. (2014). Climate change impacts in the United States Third National Climate Assessment.

Mugenda, O.M and Mugenda. A.G (1999). Research methods. Quantitative and qualitative . Approaches. (pp. 46 - 48). Nairobi, Kenya: ACTS Press.

Mugenda, O.M. and Mugenda A.G. (2003), Research Methods: quantitative and . Qualitative approaches. ACTS Press, Nairobi.

Mutoko, M. C., Hein, L., & Bartholomeus, H. (2014). Integrated analysis of land use changes And their impacts on Agrarian livelihoods in the western highlands of Kenya. Agricultural Systems, 128, 1-12

NEMA (2008). Effect of Climate Change and Coping mechanism. State of the Environment Report Kenya 2006/7.

Ngaira, J.K W. (2009). Challenges of water resources management and Food production In a Changing Climate in Kenya. Journal of geography and regional planning Vol 2(4), 079-103, April, 2009.

Omondi, P., Ogallo, L.A., Anyah, R., Muthama, J.M. and Ininda, J. (2013). Linkages between global sea surface temperatures and decadal rainfall variability over Eastern Africa . Region. International Journal of Climatology, 33: 2082–2104.

Omondi, P. A. O., Awange, J. L., Forootan, E., Ogallo, L. A., Barakiza, R., Girmaw, G. B., & Komutunga, E. (2014) Changes in temperature and precipitation extremes over Greater Horn of Africa region from 1961 to 2010.International Journal of Climatology 34(4), 1262-1277.

Owing J Window S F O and Chemilil, C M, (2005) Nutrients in runoff from a clay loam

Soil protected by a narrow grass Strips journal of soil and Tillage Research (Elsevier), 88, 116-122.

Olang, L. O. and Kundu, P. M. (2011). Land Degradation of the Mau Forest Complex in Eastern Africa: A Review for Management and Restoration Planning. In ―Environmental Monitoring‖ (E. Ekundayo, Ed.). InTech. Owido, S. F. O, Chemelil, C. M., Nyawade F. O. & Obadha,

W.O (2003). Effects of induced soil compaction on bean (Phaseolus Vagaries) seedling Emergence from a Haplic phaeozen soil. Agricultural Tropica. ET subtropica, 36, 65-69.

Roy, P. S., Dutt, C. B. S. & Joshi, P. K. 2002: Tropical forest resource assessment and Monitoring. Tropical Ecology 43, 21-37.

Rosenzweig, C. & Tubiello, F. (2007) Adaptation and mitigation strategies in agriculture: An analysis of potential synergies. Mitigation and Adaptation Strategies for Global Change, 12, 855-873 .

Rwigi 2014. Analysis of the potential impacts of climate change and Deforestation on the surface water yields From the the Mau Forest Complex catchments in Kenya. Pp. 105.

Were, K., O. B., & Singh, B. R. (2013)? Remotely sensing the spatial and temporal land Cover changes in Eastern Mau forest Reserve and Lake Nakuru drainage basin, Kenya. Applied Geography, 41, 75-86.

Were, K., Dick, O. B., & Singh, B. R. (2014)? Exploring the geophysical and Socio-economic determinants of land cover changes in Eastern Mau forest reserve And Lake Nakuru drainage basin, Kenya. GeoJournal, 79(6), 775-790.

World Wide Fund for Nature (WWF). (2006). Climate change impacts on East Africa: A review . of scientific literature. Gland, Switzerland

PP. Smith ET. Al, 2007: Mitigation contribution of Working Group111 to the Fourth Assessment Report of the IPCC (Cambridge univ. Press, Cambridge 2007), PP.498 -540

UNEP/KWS/KFWG/ENSDA (2008): Mau complex under siege; Values and Threats; A presentation by United Nations Development Program, Kenya Wildlife Service, Kenya Forest Working Group, and Ewaso Nyiro Development Authority May 2008, 25

UNEP/KFWG, (2006): Eastern and South West Mau forest reserves; Assessment and Way Forward; a presentation by: A presentation by United Nations Development Programme, Kenya Forest Working Group, Department of Resource Surveys and Remote Sensing, EU – Biodiversity conservation Program

UNEP. (2005). Africa Environmental Outlook: Past, Present and Future, Perspective: United Nations Environmental Program, Cambridge, UK, 291-296.

UNEP. (2009). Kenya: Atlas of our changing environment. Division of Early Warning and Assessment (DEWA) United Nations Environment Programme Nairobi, Kenya.

USAID/Promara (2010). Assessment on land Administration, land/natural resource Management, food security and rural livelihoods in the upper mara river basin –

Mau ecosystem. April, 2012

Zhou, Q., (1999): Digital Image Processing and Interpretation: Remote Sensing and Image Interpretation, Department of Geography, Hong Kong Baptist University Kowloon Tong, Kowloon, Hong Kong, 50

Zhang, Q., Devers, D., Desch, A., Justice, C.O. and Townshend, J., 2005. ‗Mapping Tropical . Deforestation in Central Africa', Environmental Monitoring and Assessment, Vol. 101, pp. 69-83.

HOUSEHOLD SURVEY QUESTIONNAIRE

Dear respondent

I am a postgraduate student at the University of Nairobi studying science in climate Change.

The questionnaire is intended to get your views on the level of food production on your farms, the factors affecting production and how you think deforestation has impacted on climate change and their implications on food production in South West Mau.

As residents of this area, you have been selected as one of the people to provide accurate and reliable information on about the issues below. Your responses will be accorded utmost confidentiality and are purely for academic purposes.

PART A: LOCATION OF RESPONDENT

Questionnaire Number…………………… Village………………………………..

Location …….………..………………… Ward……………………………………..

PART B: DEMOGRAPHIC INFORMATION

Gender : Male ( ) Female ( )

For how long have you lived in this location

0-5 years ☐

6-10 years ☐

11- 20 years ☐

Over 20 years ☐

What is your age in years 18-34 ( ) 35- 39 ( ) 40 – 44 ( ) 45-49 ( ) 50 &above ( )

Did you attend school? Yes ( ) No ( )

If Yes, up to what level primary ( ) Secondary ( ) College ( ) University ( )

What is the size of your household (…………..No of persons).

What is your source of income? Farmer [ ] Salaried [ ] Self-employment [ ] Business [ ] Others [ ]

What is the approximate size of your farm? (……………….Acres)

PART C: FOOD PRODUCTION LEVEL AND FACTORS AFFECTING IT

1. How many years, months have you lived in this area? (………………..)Years/months

2. Does your household normally undertake crop farming? Yes ( ) No ( )

3. If yes in (2) above, is it done by irrigation or rain fed? Irrigation [ ] Rain fed [ ]

4. List type of crops that you grow in your area? ……………………………………………

5. What area of the land is under crops…... trees……….. Pasture ……………

6. Rank the following factors affecting your food production from the most the list factor.

Factor	Very much	Much	Not very much	Little effect
Droughts/high temperatures				
Unpredictable rain seasons				
Soil infertility				
Soil erosion				
Others(pest, disease)				

6. What are the changes observed in this forest in terms of change in forest cover in the last?

20 years? Drastically reduced [ ] much reduced [ ] little reduction [ ] No change [ ]

7. What do you think are the main causes of deforestation in this forest adjacent to your

Farms?

Cause	Main cause	Not a main cause	A little cause	Don't know
Population expansion				
Illegal logging				
Agriculture expansion				
Infrastructure development				
Charcoal burning				
Others				

PART D: CLIMATE CHANGE INFORMATION

What do you understand by climate change?

According to you has the seasons been changing leading to droughts for the last 20 years?

How many years have you been in farming? {1-5}, {6-9}, {10 and above.

How has been your experience in terms of changes in food production due to climate change?

What is the extend of climate variability effect on food production in this area

Have you noticed unpredictable weather patterns?

How has the reduction in crop yields in your farms?

6. How has been your production overtime for the last ten years up to now? Increased [ ]

Decreased [ ] Remained the same [ ]

How have been the changes in rainfall amount over time? Increased…….. decreased [ ]

No changes [ ]

8. Do you think these changes have affected your food production? Yes [ ] No [ ]

9. If yes, how has the crop yield changed over the seasons –stable [ ] increased [ ] declined [ ] Not changed [ ]

10 Do you have enough food for your household currently to sustain you for 2 years? Yes [ ]

No [ ]

11 What do you think about the next two years? Will be enough [ ] Will not be enough [ ]

12. How would you rate the quantity of food in your household? Very good [ ] Good [ ] Bad [ ] Very bad [ ]

13. How has been the change in weather patterns, seasons for the last two years? Predictable [ ] Unpredictable [ ]

14. If unpredictable, do you think it has affected your food production at farm level? Yes [ ] No [ ]

15. If yes, how has it affected your Food production for the last two years up to now? Greatly affected [ ] slightly affected [ ] Not affected [ ]

16. How has been the reduction in yields in your farm in terms of bags 20-15……….. 20-10………… 20-8………….. 20-5………….. 20-2………….. Not sure…………

17. Have you ever accessed any forecast information for the past 15 years for any rainy season? Yes [ ] No [ ]

18. If yes in (15) above, what source of information and do you have confidence in forecasts Yes [ ] No [ ]

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

[ ] Forecasts about when rains are expected to fall in your area

[ ] Forecasts about when rains are expected to end in your area

…………………………………………………………….

[ ] Forecasts about whether the amount of rainfall will be above average, normal or below average

[ ] Forecasts about the distribution of the rainfall during the season

19. How do you think the following climate related factors have changed in the past 15years? 20. How do you think climate variability has affected food production in your farm in the past 15 years?

21. Have you experienced any floods in the area for tis duration? Yes [ ] No [ ]

22. If yes how was the frequency of occurrence or they occur after how long………………

23. Have you experienced any soil erosion in your farms Yes [ ] No [ ]

24 If yes, how severe is it very severe……. Not severe…………….

25What do you think are the causes of the erosion in your own view………………..

Temperatures

Hotter	Much Hotter	Stayed the same	Cooler

Level of food productivity

Very high	High	Low	Very low

Rainfall occurrence

Much more variable	More variable	Stayed in the same	Less variable

PART D:

Perception Question/Household questionnaire

1	Do you understand what climate change is?	1	2	3	4
2	How much do you understand about climate change?				
3	Do you believe that climate change is real?				
4	Do you believe that climate change has reduced crop				

	production in your area				
5	Do you believe that all people should know something about climate change				
6	Deforestation has negative influence on agriculture as it leads to climate change which leads to lower yields.				
6	The erratic weather patterns experienced in the region is as a result of forest depletion.				
7	The declining crop yields is linked to soil degradation due to deforestation				
8	Do you believe that food security is changing from better to worse due to rainfall and temperature changes?				
9	Do you participate in any activity to adapt to climate change on food security in your area?				
10	Do you associate reduced food production with climate change?				
11	Do you believe that problems related to climate change and food security will be reduced if early warning measures were communicated in time?				
14	Do you believe that Deforestation and degradation result to climate change?				
15	Do you believe that climate change has reduced crop production in your area?				
16	Do you believe that food security has improved in your area overtime?				
17	Do you belief that the early warnings are useful to you?				

18	Do you agree that the meteorological department always makes timely the early warnings				

Thank for participating

PATRICIA N. KITHEKA

CHECKLIST FOR INTERVIEW SCHEDULE

TOPIC: CLIMATE CHANGE AND FOOD PRODUCTION

Name:

Institution: ___________________________

Position Held: _________________________

Date: _________________

1. How has the Climate changed for the last 15years?

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2. What is the extend of climate change effects on food production in the study area
3. What are the main livelihoods of the people in this area?
4. What are the main crops grown in this area?
5. Do you think in your own views there is enough food production in this area
6. Do you depend on rain-fed agriculture most of the times?
7. Has there been change of rainfall patterns leading to unpredictable weather patterns?
8. How has this impacted on your food production?

9. What do you think should be done to prevent climate change?

Thank for your Participation