University of Nairobi

School of Engineering

ASSESSMENT OF THE EFFECTS OF CLIMATE CHANGE ON MAIZE PRODUCTION USING GIS: CASE STUDY OF RAINFALL VARIATION IN TRANS-NZOIA COUNTY.

BY

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DECLARATION

I, Ruth Tamaro Nyaundi, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other institution of Higher Learning.

Ruth Tamaro Nyaundi

………………… ……………............ ………………

Name of student Signature Date

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

………………………… .... ………

Name of supervisor Signature Date

DEDICATION

This project is dedicated to my late father Mathew Nyaundi Mirera and my mother Eunice Mathew and my elder brother Justine Nyaundi who sacrificed so much financially and gave much moral support to see me through my entire education and well-being during my studies.

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ABSTRACT

Climate change can be defined as change in the usual weather found in a place, this could be a change in how much rain a place usually gets in a year or it could be a change in a place's usual temperature over time which can last over thousand or million years. Majority of the people in Kenya and particularly those in Trans-Nzoia County, rely on small scale farm enterprises for their livelihood. For a long time, people of Trans-Nzoia have grown maize and beans. Maize is the most important cereal crop in Kenya because it is a staple food to most Kenyans.

Too little or too much water can be a problem. In many places, people depend on rain as a source of water for watering crops, and other uses. However, heavy rain can cause flooding. Due to this aspect of global climate change agriculture and food supply have been affected in many ways. This report demonstrates how GIS can be used as a tool to integrate, manage, and visualize spatial data as a useful solution for mapping and analysing the current effects and future trends of maize production in the county.

An Assessment of the effects of climate change on maize production has been carried out in Trans-Nzoia County. The study will focused on the effects of changing rainfall patterns on food production, to establish the rainfall trends between 1982 and 2012 at the four year interval, to establish the corresponding maize production in the county, to correlate the maize production data and rainfall data and to use any relationship obtained to predict maize production for the year 2017.The study aimed at establishing current production trends of maize and how the changes in rainfall patterns are affecting maize farming over the years.

The study applied a surface modeling methodology using the Geostatistical analyst tool in Arc GIS which has interactive tools to visually investigate data prior to analysis. The tools allowed investigation and distribution of data, visualization of the spatial correlation within and between datasets, came up with a prediction model which produced the figures similar to those of 2016 making the model appropriate for any prediction given the previous year's yields, created surfaces from sample data by interpolation methods, evaluated how the model performed and looked for systematic trends in the data. Data that was collected from various agricultural institutions and the National Cereals Board for the county revealed the previous and current production trends of maize in Trans-Nzoia County. Rainfall data from the meteorological department was converted into 1972-2012 trend estimates, and interpolated using a rigorous geo-statistical technique and analyzed to look for systematic trends in the data.

The findings of the study indicated the current production levels of maize and how it has been changing over the years due to changing rainfall patterns, hence the extent of vulnerability to climate in maize production. The study has shown that rainfall accounts for only about 11% of the variation in maize production. Further studies, incorporating other factors (e.g. temperature), are therefore recommended in order to fully explain the observed variation in maize production levels.

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ARTES	-	AFRICAN RAINFALL AND EVALUATION SYSTEM
ASALS	-	ARID AND SEMI ARID LANDS
CO_2	-	CARBON DIOXIDE
		DEVELOPMENT
DRSRS	-	DEPARTMENT OF REMOTE SENSING AND RESOURCE
EPA	-	ENVIRONMENTAL PROTECTION AGENCY
GHG	-	GREENHOUSE GASES
IPCC	-	PANEL ON CLIMATE CHANGE
KALRO	-	KENYA AGRICULTURAL AND LIVESTOCK RESEARCH
MAM	-	MARCH, APRIL, MAY
OND	-	OCTOBER, NOVEMBER, DECEMBER
		ORGANIZATION
WEF	-	WORLD ECONOMIC FORUM

CHAPTER 1:INTRODUCTION

1.1 Background

Climate change is one of the key future challenges for both developed and developing countries. With a growing world population, high food demands, water and energy and a dwindling natural resource base, climate change will act as a 'threat multiplier' (CNA, 2007), aggravating resource scarcity and putting further pressure on socio-ecological systems. Storms, severe droughts, heat waves, land and forest degradation and salinization of groundwater resources that we already see today are often viewed as a foretaste of climate change interacting with other anthropogenic impacts on the environment. Climate change can be defined as the change in the usual weather found in a place, this could be a change in how much rain a place usually gets in a year or it could be a change in a place's usual temperature over time which can last over thousands or millions years.

Maize is Kenya's most important crop; the annual maize demand is between 38 million and 51 million bags based on per capita consumption of between 72kg and 98kg per person per year. (Government of Kenya, 2011) data indicated that maize accounts for more than 51 per cent of all staples grown in the country. Majority of the people in Kenya and particularly those in Trans-Nzoia County, rely on small scale farm enterprises for their livelihood. For a long time, people of Trans-Nzoia have grown maize and beans. Kenya continues to face challenges in its food production and this has impacted on the food security


Plate 1:1: Maize that has just been harvested dried up and ready for storage in Trans-Nzoia.

Too little or too much water can be a problem. In many places, people depend on rain as a source of water for watering crops, and other uses. However, heavy rain can cause flooding. Due to this aspect of global climate change agriculture and food supply have been affected in many ways. GIS will be used as a tool to integrate, manage, and visualize spatial data as a useful solution for mapping and analysing the current effects and future trends of maize production in the county.

Declining trends of quantities of maize produced have been evident in the country with the recent loud proclamation of the government that maize from Mexico had arrived at the port of Mombasa. Majority of farmers have recorded significant declines in the quantities of maize produced (Nation, 2017). These and many other issues need to be ascertained so as to provide a plausible explanation to the situation in country.

1.2 Problem Statement

The main staple crops in Kenya are maize, wheat, rice, sorghum and Irish potatoes. Annual maize production is about 40 million bags. This amount is sufficient only for human consumption leaving about one million bags which is insufficient for industrial processing, seeds, animal feeds and strategic reserves. Kenya's maize production is largely dependent on rain-fed agriculture characterized by risk and uncertainty. According to Manana, (2014) almost 57 percent of the population lives in poverty, basically relying on climate-sensitive economic activity. Over time, there has been little yield attained in Kenya with the highest production level being reported in 1982, 1986 and 1996. Yield gains have dropped by 1kg/ha/year between 1980 and 2013 and if the same trend continues we expect gross maize output to decline over time.

However, despite the importance of maize to the country, production especially in the last decade has been poor. The average national yields are about 1.67 tons per hectare compared to yields of up to 6 tons per hectare in the developed countries. Since 1994, maize consumption has outstripped production and Kenya has to meet the deficit through imports. Erratic weather conditions have been blamed for a succession of maize crop failures forcing the Kenyan government to import maize to feed its population

Kenya experiences major droughts every decade and minor ones every three to four years. In recent years, critical drought periods in the country were experienced in 1984, 1995, and 2000 and 2005/2006 Samuel, (2017). The impacts of these droughts on the population are increasing due to high population growth and increasing encroachment of agricultural activities in the arid and semi-arid regions, classified as ASALs. The droughts are often followed by periods of intensive rainfall. Many of the impacts of climate change appear through changes in extreme events such as droughts and floods. Such extremes result in severe human suffering, and hamper economic development and efforts and poverty reduction. Unfortunately, assessments of climate change are often limited to mean temperature and precipitation. Knowledge of changes in extremes is sparse, particularly for Africa. In some regions, different models project different trends in wet and dry extremes. In other regions, however, models show clear trends such as increasing drought in the Kalahari and increasing floods in East Africa (KNMI 2006).

Owing to the changes in the climatology and weather variations, maize production has drastically dropped over the recent years due to the cruel weather hazards like prolonged long rains caused by changing climate. This has led to less maize harvested in tons per hectare hence not meeting the growing demand of the Kenyan population. Due to decreased maize production in Trans-Nzoia County, importation of Maize from neighboring nations has become the order of the day given that the county of Trans-Nzoia alone can feed all Kenyans with proper integrated geospatial technology to curb the delayed rains which obstruct maize growth.

Most studies conducted by other scientists on the impact of climate change on the agricultural sector in Kenya, have analysed the impact of climate in general agriculture. Therefore there is need to carry out an in depth research on crops at the individual level to determine how much they have been affected by the changing climate and their contribution to food insecurity. This way farmer can get answers to questions like; why has the maize production gone low? How has the changing rainfall patterns affected maize production and how does this aspect of climate change explain the decline in production trends of the farm enterprises?

Due to lack of more integrated approaches in climate, rainfall and production there is need for integrated geospatial approaches to cub the impacts of changing rainfall patterns on food crops especially maize production, water availability and the dry spell. There is also need to improve understanding of how local weather patterns will change with global warming. Since different crops will have different weather sensitivities that will need to be taken into account when considering the impacts of climate change

1.3 Objectives of the study

a. General Objective

The main objective of this study is to use geospatial technology to assess the effects of changing rainfall patterns on maize production in Trans-Nzoia County.

b. Specific objectives

i. To establish the rainfall trend in Trans-Nzoia between 1982 and 2012 at four year intervals

ii. To establish the corresponding maize production trend in the county
iii. To correlate the maize production data and rainfall data.

1.4 Organization of the report

This project report is organized into five chapters as follows

Chapter one contains the background of the study, brief information on the area of study, information on the major aspects discussed and the objectives of the study.

Chapter two contains a review of literature on climate change and its impacts on crop production.

Chapter three describes the methodology used in the study.

Chapter four gives information on the results and the analysis of the results and the discussions of the findings of the study.

Chapter five provides the conclusions and the recommendations from the study.
References follow at the end of the report.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

More than four billion years ago since the earth was formed, its climate has periodically shifted from cool to worm and back again. Sometimes dramatically fossils, preserved in ancient sedimentary rocks, provide evidence that population of tropical plants and animals once thrived in Europe and elsewhere where today's climate is cool and temperate. Dunbar (2015).

Climate change is a reality and has been experienced across the entire globe. This chapter reflects on climate concepts and understanding of climate change as a typical pattern of weather over the long term. It also highlights the causes and the impacts of climate change on food production. Climate change has been perceived in terms of extreme heat and flood, heavy rains and drought, the changing rainfall patterns, and the rise in sea levels. All these factors have huge impacts on agriculture. The impacts are more often than not negative, and evident in food production, health, water resources, ecosystem, shelter, vulnerable populations and national security. It further predicts the future of climate change in the study area and the similar studies done before on the area.

2.2 The climate change concept

The term climate comes from the Greek word “klinein”, or "slope", describing how the angle that the sun hits the earth varies in different regions. Dunbar (2015) describes climate change as a change in Earth's overall climate. This could be a change in Earth's average temperature, or it could be a change in Earth's typical precipitation patterns. In a nutshell, climate change occurs when long-term weather patterns are altered for example, through human activity.

Any process that causes adjustments to a climate system from a volcanic eruption to a cyclical change in solar activity could be described as creating "climate change". The climate of a region or city is its typical or average weather .Climate change, therefore, is a change in the typical or average weather of a region or city. This could be a change in a region's average annual rainfall, or it could be a change in a city's average temperature for a given month or season.

2.3 Greenhouse gases (GHG)

Global changes in atmospheric composition arise from anthropogenic emissions of greenhouse gases, such as carbon dioxide that results from the burning of fossil fuels, methane and nitrous oxide from various human activities. Much like the glass of a greenhouse, gases in our atmosphere sustain life on Earth by trapping the sun's heat. These gases allow the sun's rays to pass through and warm the earth, but prevent this warmth from evading our atmosphere into space. Without naturally occurring, heat-trapping gases mainly water vapor, carbon dioxide and methane Earth would be too cold to sustain life. Earth’s atmosphere is made up of oxygen, a large amount of nitrogen and a small percentage of greenhouse gases. Greenhouse gases act like a blanket around the Earth. They trap warmth from the sun and make life on Earth possible. Without them, too much heat would escape and the surface of the planet would freeze.

(Government of Kenya, 2017) reports that, increasing the concentration of greenhouse gases in the atmosphere causes the Earth to heat more and the climate to change. This process is often called global warming but it is better to think of it as climate change because it is likely to change other aspects of climate as well as temperature, and also bring about more extreme climate events such as floods, storms, cyclones and droughts.

Climate change is used interchangeably with another phrase “global warming “reflecting the strong warming trend that scientists have observed over the past century. Strictly speaking, however, climate change is a more accurate phrase than global warming, because rising temperatures can cause a host of other climatic impacts, such as changes in rainfall patterns. (UK Met, 2017) The danger lies in the rapid increase of carbon dioxide and other greenhouse gases that intensify this natural greenhouse effect. Plate number 1 shows the release of the greenhouse gases to the atmosphere from an industry, one of the causes of climate change.

Plate 1:2 : Picture showing industrial pollution in the developed countries

Today's atmosphere contains 42 per cent more carbon dioxide than it did at the start of the industrial era. Levels of methane and carbon dioxide are the highest and they have been in nearly half a million years. The Kyoto Protocol covers six greenhouse gases: carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons and sulphur hexafluoride. Of these six gases, three are of primary concern because they are closely associated with human activities. Zusuki (2016)

Carbon dioxide is the main contributor to climate change, especially through the burning of fossil fuels. Methane is produced naturally when vegetation is burned, digested or rotted without the presence of oxygen. Large amounts of methane are released by cattle farming, waste dumps, rice farming and of oil and gas production. Nitrous oxide, released by chemical fertilizers and burning fossil fuels, has a global warming potential of 310 times that of carbon dioxide.

Biket (2017) the startling rate of increase in total anthropogenic greenhouse gas (GHG) emissions in the last decade has distorted the climate. With no a reduction of GHG emissions, further warming and changes in all components of the climate system will occur. As a result, the earth is very likely to be warmer than cold days and nights. Food production centre around the world have been experiencing climate change.

2.4 What is Causing Earth's Climate to Change?

Life on Earth is possible because of the warmth of the sun. While some of this incoming solar radiation bounces back into space, a small portion of it is trapped by the delicate balance of gases that make up our atmosphere. Without this layer of insulation, Earth would simply be another frozen rock hurtling through space. Carbon dioxide (CO_2) is the most important gas in this layer of insulation.

Carbon is stored all over the planet in plants, soil, the ocean, and even us. We release it into the atmosphere as carbon dioxide through activities such as burning fossil fuels (coal, oil and gas) and cutting down trees. As a result, today's atmosphere contains 42 per cent more carbon dioxide than it did before the industrial era.

We have released so much carbon dioxide and other greenhouse gases that our planet's atmosphere is now like a thick, heat-trapping blanket. By disrupting the atmospheric balance that keeps the climate stable, we are now seeing extreme effects around the globe. It's like a thermostat that's gone haywire and just doesn't work the way it should. This results into climate changes, and it gets warmer. Since 1900, the global average temperature has risen by 0.7 degrees Celsius, and the northern hemisphere is substantially warmer than at any point during the past 1,000 years. Global warming has already begun.

(a) How climate change occurs

Climate change might result from so many things, natural factors and processes, human activities and many other things can cause climate to change all on its own. Earth's distance from the sun can change. The sun can send out more or less energy, oceans can change and when a volcano erupts, it can change our climate. The term “climate change” is often used interchangeably with the term “global warming” but they are different from each other**.** Global warming refers to an average increase in the temperature of the atmosphere near the earth’s surface, which can contribute to changes in global climate patterns (EPA, 2004). It is one of the most controversial. Climate change occurs when long-term weather patterns are altered

(b)Human Activity

Most scientists acknowledge that humans can change climate too. People drive cars, heat and cool their houses. They cook food and all these things use energy. One way we get energy is by burning coal, oil and gas. Burning these things puts gases into the air. The gases cause the air to heat up. This can change the climate of a place. It also can change Earth's climate therefore it qualifies as the primary cause of climate change since it emits greenhouse gases into the atmosphere i.e. primarily carbon dioxide. Other human activities, such as agriculture and deforestation, also contribute to the proliferation of greenhouse gases that cause climate change (USA Govt, 2016).

While some quantities of these gases are a naturally occurring and critical part of Earth’s temperature control system, the atmospheric concentration of CO_2 did not rise above 300 parts per million between the advent of human civilization roughly 10,000 years ago and 1900. Today it is at about 400 ppm, a level not reached in more than 400,000 years.

The People who study the Earth observe that Earth's climate is getting warmer and that the Earth’s climate is always changing. There have been times when Earth's climate has been warmer than it is now or it used to be and there have been times when it has been cooler than it is now. These small changes in Earth's temperature can have big effects although they may seem to be insignificant. These times can last thousands or millions of years.

Scientists think that Earth's temperature will keep going up for the next 100 years. This would cause more snow and ice to melt. Oceans would rise higher. Some places would get hotter. Other places might have colder winters with more snow. Some places might get more rain. Other places might get less rain. Some places might have stronger hurricanes. Some effects are already happening. Warming of Earth's climate has caused some snow and ice to melt. The warming also has caused oceans to rise. And it has changed the timing of when certain plants grow.

2.5 Climate Change in Kenya

The Kenyan climatic conditions have been undergoing some change, the average temperature in Kenya have increased by 1degree C since 1960 while translates to about 0.21 degree per decade.(Mc Sweeney ,2008)

MEMR (2009) Observed that the variability of annual rainfall has increased. Rainfall between March and May (long rains) has shown decline while rainfall between October and December(short rains)has shown increase Furthermore increasing temperature, change in rainfall patterns and ,extreme weather conditions such as drought have been evident in the recent times and floods have become frequent. This change in climatic conditions is projected to more likely continue in the near future. Kenya will experience an increase in temperature in those regions. Between 1degree Celcius and 5 degree Celcius by the year 2020 while mean annual rainfall is also going to increase particularly in the short rainy season in the high to medium potential areas. Arid and semi-arid areas will likely experience depressed rainfall thereby exacerbating the drought condition being experienced in those regions.

Just as the surface of the Earth is not flat, the surface of the oceans is also not flat, and this sea surface is not changing at the same rate globally. For instance, it is known that the absolute water level height is higher along the West Coast of the United States than the East Coast. "Global Sea Level Rise" refers to the increase currently observed in the average Global Sea Level Trend, which is primarily attributed to changes in ocean volume due to two factors: ice melt and thermal expansion. Melting of glaciers and continental ice masses, such as the Greenland ice sheet, which are linked to changes in atmospheric temperature, can contribute significant amounts of freshwater input to the Earth's oceans.

The Intergovernmental Panel on Climate Change (IPCC) Report estimates that the global sea level rise was approximately 1.7-1.8 millimetres per year (mm/yr.) over the past century (IPCC, 2007), based on tide station measurements around the world, with projected increased trends in sea level in the 20th Century based on global climate models. Because the heights of both the land and the water are changing, the land-water interface can vary spatially and temporally and must be defined over time.

Plate:1:3:Picture showing one of the Globally, eight of the world's 10 largest cities near a coast, according to the U.N. Atlas of the Oceans**.**

Sea level rise is caused primarily by two factors related to global warming the added water from melting ice sheets and glaciers and the expansion of sea water as it warms. A warming climate can cause seawater to expand and ice over land to melt, both of these can cause a rise in sea level. Sea level can rise by two different mechanisms with respect to climate change. First, as the oceans warm due to an increasing global temperature, seawater expands taking up more space in the ocean basin and causing a rise in water level. The second mechanism is the melting of ice over land, which then adds water to the ocean. (Report on National Climate Change Assessment Report U.S .A 2017)

Understanding trends in sea level, as well as the relationship between global and local sea level, provides critical information about the impacts of the Earth's climate on our oceans and atmosphere. Changes in sea level are directly linked to a number of atmospheric and oceanic processes. Changes in global temperatures, hydrologic cycles, coverage of glaciers and ice sheets, and storm frequency and intensity are examples of known effects of a changing climate, all of which are directly related to, and captured in, long-term sea level records. Sea levels provide an important key to understanding the impact of climate change, not just along our coasts, but around the world. By combining local rates of relative sea level change for a specific area based on observations with projections of global sea level rise (IPCC, 2007), coastal managers and engineers can begin to analyse and plan for the impacts of sea level rise for long-range planning.

2.6 Climate change and rainfall patterns

Climate models predict that the addition of heat-trapping gases in the atmosphere will shift precipitation in two main ways. The first shift is in a strengthening of existing precipitation patterns. This is commonly called "wet get wetter, dry get drier." Rising sea levels due to the melting of the polar ice caps (again, caused by climate change) contribute to greater storm damage; warming ocean temperatures are associated with stronger and more frequent storms; additional rainfall, particularly during severe weather events, leads to flooding and other damage; an increase in the incidence and severity of wildfires threatens habitats, homes, and lives; and heat waves contribute to human deaths and other consequences. Some examples of how climate change has affected rainfall patterns around the world include the following:

2.6.1 Russia

According to a report by the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet, 2011) monitoring data and model calculations show that Russia’s climate is more susceptible to global warming than the climate of many other regions of the world. Climate warming in Russia has been registered as taking place at a much faster pace than the warming seen in the rest of the world.

Highly interesting results were obtained during a study on the quantitative evaluation of the impact of climate change on crop yields in Russia conducted by the Russian Research Institute of Agricultural Meteorology under the patronage of the Environmental Ministry of Russia and Roshydromet, which has been doing scientific research in this area for many years. Safonov (2013). Climate change is already having a negative impact on agricultural production in Russia, especially grain production, since this sector is perhaps the most dependent on weather and climate factors. In 2012 (which was a rather good year compared to drought-stricken 2010), gross yield of grain and leguminous crops shrank by 17 per cent compared to the country average in 2006–2010, and 25 per cent compared to 2011. At the same time, all of the leading grain-producing regions saw a considerable decrease in grain production, in some cases reaching 50 per cent of the total output for 2006–2010. Safonov,(2013).

The actual statistics for 2010 and 2012 shows that declining production, which has been triggered primarily by drought could exceed the forecast published by the Russian Research Institute of Agricultural Meteorology. It is more important, however, that the forecasts are consistent with the actual data; the changing climate is already affecting grain production in Russia. Russia will experience a mix of positive and negative impacts on food and water supply in the period to 2030. The net impacts in these important areas will depend heavily on the extent to which adaptation measures can be implemented in an affordable and timely manner, but doing so will be difficult. Experts project that Russia will experience an increase in total water supply in the period to 2030 On the other hand, many other parts of Russia will experience worsening water shortages, including densely populated industrial regions that are projected to experience increases in water demand of 5-25 per cent

Regarding food supply, the longstanding popular presumption in Russia has been that a warmer global climate would translate into a significantly more hospitable Russian environment for agricultural production. Indeed, there are several respects in which climate change by 2030 will reduce longstanding challenges for Russian agriculture. First and foremost, growing seasons have already become longer and are predicted to become longer still.

2.6.2 U.S.A

Since 1900, average annual precipitation over the U.S.A has increased by roughly 5 percent. This increase reflects, in part the major drought of the 1930s, which made the early half of the record drier. There are important regional differences. For instance, precipitation since 1991 increased the most in the Northeast 8%, Midwest 9% and southern great plains8% while much of the Southeast and southwest had a mix of areas of increase and decreases. The Northern U.S is projected to experience more precipitation in the winter and spring, while the Southwest is projected to experience less, particularly in the spring. The projected changes in the northern U.S are a consequence of both warmer atmosphere and associated changes in large scale weather patterns.

On average, the world is already getting more precipitation now than it did 100 years ago: 6 per cent more in the United States and nearly 2 per cent more worldwide. The climate change effects vary by region, though. For example, states in the Northeast are getting more precipitation than they used to get, but Hawaii is getting less. Precipitation is expected to increase in higher latitudes and decrease in areas closer to the Equator. The northern United States will become wetter while the South, particularly the Southwest, will become drier. Too little or too much water can be a problem. In many places, people depend on rain and snowmelt to fill lakes and streams and provide a source of water for drinking, watering crops, and other uses. However, heavy rain can cause flooding (USA Govt, 2016).

Climate change is affecting where, when, and how much water is available for people to use. Many parts of the world already have very little water, and climate change might make this problem worse. Rising temperatures, changing precipitation patterns, and increasing droughts will affect the amount of water in lakes, rivers, and streams, as well as the amount of water that seeps into the ground to replenish ground water 2007, a major drought hit the south-eastern United States. Lake Lanier, which is the main source of drinking water for the Atlanta area, was reduced to record–low water levels. People had to use less water in their homes and businesses and make other changes, such as not watering their lawns.

Many places rely on snowmelt to fill the lakes, rivers, and streams that help keep drinking water reservoirs full and provide water to irrigate crops. For example, many parts of the western United States depend on water from the Colorado River, which is fed by melting snowpack in the Rocky Mountains. Less snowpack and earlier snowmelt will reduce the amount of water flowing into the Colorado and other rivers.

2.6.3 The Sahel

In the Sahel, rainfall is by far the most decisive climate variable affecting the lives of people; some authors consider that this variable alone can determine the evolution of the environment in this region of the world. Rainfall can therefore be regarded as the most appropriate indicator to characterize or analyse climate change in the Sahel. Changing rainfall in the Sahel is characterized by two distinct periods, namely: the period of 1950 – 1969, which was marked by a succession of wet years and the period 1970 – 1993 marked by the persistence of dry years. Some analysis that has been conducted over the same concludes at the end of the phenomenon while others stress its continuity. Another aspect of the question is whether the situation being experienced by the Sahel rainfall is a manifestation of climate change or a natural variability of the phenomenon.

The impacts of climate variability and change on Sahelian ecosystems are clear. The sectors most affected are Agriculture, through land degradation, decrease in productivity of crops, livestock and water resources. Impacts on these sectors have negative effects on the populations given the fact that rural populations account for more than 80% of the entire population. In the Sahel, rainfall is by far the most decisive climate variable affecting the lives of people; some authors consider that this variable alone can determine the evolution of the environment in this region of the world. Rainfall can therefore be regarded as the most appropriate indicator to characterize or analyse climate change in the Sahel.

One of the most significant climatic variations has been the persistent decline in rainfall in the Sahel since the late 1960s. The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994. This was considered to be the wettest year of the past 30 and was thought to perhaps indicate the end of the drought. Dore (2005) Water stress, triggered by increasing temperatures, reduction in number of rainy days and increasing length of dry spells will likely impact rice and wheat production in Asia, the United States Teng (2015)

Why does it matter?

Too little or too much water can be a problem. In many places, people depend on rain and snowmelt for agricultural production to fill lakes and streams and provide a source of water for drinking and other uses. However, heavy rain can cause flooding. Rising temperatures will intensify the Earth's water cycle, increasing evaporation. Increased evaporation will result in more storms, but also contribute to drying over some land areas. As a result, storm-affected areas are likely to experience increases in precipitation and increased risk of flooding which will lead to poor crop growth, while areas located far away from storm tracks are likely to experience less precipitation and increased risk of drought (USA Govt, 2016)

2.7 Effects of climate change.

Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change. Rainfall is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future. Changes in rainfall patterns can dramatically change agricultural productivity. Increase in rain can provide water needed for crop production in areas where there is little crop production. On the other hand decrease in rainfall will lead to decreased maize production and can have a long term effect out of the immediate rainfall areas. Nelson (2009).

A warmer atmosphere can hold more moisture, and globally water vapour increases by 7% for every degree centigrade of warming. How this will translate into changes in global precipitation is less clear cut but the total volume of precipitation is likely to increase by 1-2% per degree of warming. There's evidence to show that regions that are already wet are likely to get wetter, but details on how much wetter and what impacts

there will be on a local scale are more difficult to ascertain. The dry regions of the subtropics are likely to get drier and will shift towards the poles. For much of Europe, wetter winters are expected, but with drier summers over central and southern Europe.
It is the changes in weather patterns that make predicting rainfall particularly difficult. While different climate models are in broad agreement about future warming on a global scale, when it comes to predicting how these changes will impact weather – and consequently rainfall – there is less agreement at a detailed level. It is likely that in a warmer climate heavy rainfall will increase and be produced by fewer, more intense events. This could lead to longer dry spells and a higher risk of floods.

So far, any impact that climate change may have had generally on regional rainfall cannot be distinguished from natural variations. On the other hand, for some specific cases a signal is starting to emerge. A recent study showed that man-made climate change substantially increased the odds of damaging floods occurring in Narok. Some parts of the North Eastern Kenya and Nyanza are some of the leading loss of properties. Current understanding suggests that increases in heavy rainfall during the rainy season, may start to become discernible more generally in the 2020s.

Climate models and observations are improving all the time and the reliability of predictions is likely to improve significantly over the next few years. In particular, new satellites and more detailed GIS analysis models are opening up new possibilities for understanding and predicting how water cycles through the climate system.

However, the latest generation of localized weather forecasting models, represent scales down to 1km and can incarcerate these localized features. Scientists are now starting to apply these models to climate change studies, raising the possibility of much more confidence in their predictions of changes in extreme rainfall. Guardian (2013)

There have been observed changes in precipitation, but not all areas have data over long periods. Rainfall has increased in the mid-latitudes of the northern hemisphere since the beginning of the 20th century. There are also changes between seasons in different regions. For example, the UK's summer rainfall is decreasing on average, while winter rainfall is increasing. There is also evidence that heavy rainfall events have become more intensive, especially over North America.

2.8 Impacts of climate change on food production

Food-secure societies and communities have a reliable source of affordable food, sufficient to maintain a healthy diet for all. For many millions, climate change may threaten that security when it comes to keeping us properly fed, climate scientists from the Met Office and food security analysts at the World Food Programme concur that some of the world's regions could benefit from climate change, while others would be seriously debilitated by it. Although it is hard to predict what will happen at a local level, climate change could put millions at potential risk of food shortage.

Food security is closely linked to climate, and in Sudan agriculture accounts for around one third of the country's GDP, and employs around 80% of the labour force. Climate change could have a large impact on agricultural production and livelihoods in Sudan, and the World Food Program and the Met Office undertook a study on the relationship between long-term climate change and future food security.

Sudan lies at the northern most extent of the band of tropical rains known as the Inter-tropical Convergence Zone. This means it has a strong gradient of rainfall, ranging from extremely dry conditions in the north, to relatively wet conditions in the south. The climate is hot throughout the year but with seasonal rains, which can vary from year-to-year.

The large differences in rainfall across the country mean there are a wide variety of livelihoods and agricultural production systems, which correspond to the climatologically suitability of different regions. Pastoral farming dominates in the north where rainfall totals are low and the onset of the rains is unreliable; cropping systems are more prevalent in the south where the rainy season is reliably longer and heavier.

However, agriculture is mostly rain-fed in Sudan and is therefore sensitive to rainfall amounts and timings everywhere. This means that climate variability and change are key factors in the future of Sudan's economy, livelihoods, and food security. Food security is assessed by four measurements:

Plate 2:1: A picture showing a lady spreading fruits and all kinds of foods in the market

Food availability: Changes in climatic conditions have already affected the production of some staple crops, and future climate change threatens to exacerbate this. Higher temperatures will have an impact on yields while changes in rainfall could affect both crop quality and quantity. Availability means the physical presence of food through domestic production, commercial imports or food aid. Indicators of changes in food availability might include crop and livestock production trends.

Food access: Climate change could increase the prices of major crops in some regions for example, maize flour has become expensive as much as the government has tried to subsidize the prices and more worse is that it is not even available. Household's ability to acquire adequate amounts of food, through a combination of home production and stocks, purchases, borrowing for the most vulnerable people it has become a nightmare consequently lower agricultural output means lower incomes. Under these conditions, the poorest people who already use most of their income on food sacrifice additional income and other assets to meet their nutritional requirements, or resort to poor coping strategies. Indicators of food access changes might include food price trends and market flows.

Food utilization: Climate-related risks affect calorie intake, particularly in areas where chronic food insecurity is already a significant problem. Changing climatic situation could also create a vicious cycle of disease and hunger. Nutrition is likely to be affected by climate change through related impacts on food security namely, dietary multiplicity, care practices and health, a household's consumption of the food it has access to and the individuals' capacity to absorb and metabolize the nutrients.

Food stability: The climatic variability produced by more frequent and intense weather events can displease the stability of individuals' and government food security strategies, creating fluctuations in food availability; food access and food utilization, therefore food stability is the state where food is regularly and periodically present and it should be affordable for every family to meet there nutritional values. Indicators of instability include the impact of shocks such as floods and droughts on crop production. Changes in climate and increases in some extreme weather events, such as floods and droughts, could disrupt stability in the supply of food and people's livelihoods making it more difficult for them to earn a stable income to purchase food.

What will happen in the future?

Precipitation is expected to increase in higher latitudes and decrease in areas closer to the Equator. The northern United States will become wetter while the South, particularly the Southwest, will become drier. Crops are likely to reach their biological limits in current producing regions, especially with temperature increases of 4ºC above current levels. For tropical climate systems, extreme heat will limit the length of the growing season.

Rice losses are likely to be associated with an increase in temperature (resulting in higher heat stress and higher evapotranspiration), sea level rise and increased salinity in the deltas. By 2080; North-east Thailand may experience negative yield changes from 8.6 to -32.2 per cent. Teng, (2015)Under the worst case climate scenario, it is likely that maize yields will be reduced even more than what the county Agricultural officer stated before by 2050 to 2080.

In South-east Australia, warm temperatures can cause negative yield changes from 25 to 29 per cent. Due to uncertainty in rainfall, Indian wheat can experience delays in sowing period. A 10-day delay can result in losses of up to 20 per cent of yield in Northeast India and 14 per cent in Northwest India. Teng, (2015) Climate change isn't just threatening food supply and agriculture in Africa, it's a global problem, as farmers are struggling to adapt to changing growing seasons and rainfall levels, and need significant support to feed an expanding global population, demand for food is due to nearly double by 2050.
Agriculture faces the double challenge of becoming more environmentally sustainable while feeding more people. In the next 40 years, the global population is expected to increase by one-third, peaking at over 9 billion. The intensity of consumption is growing even faster; as incomes rise in up-coming markets, new members of the middle class demand more maize and dairy products, which require more resources to produce.

The link between climate change and food security is a two-way street. The industry must become accustomed to reduce emissions and ensure sustainability, but also grow to feed an increasing global population. Nearly a billion people are hungry today, and with yields set to drop 20% in some areas as a result of climate change, action is urgently needed. The tricky bit, however, is that agriculture is in part responsible for climate change. This is highlighted by a World Economic Forum report, (WEF) which shows that the industry is responsible for up to 30% of global greenhouse gas emissions.

There are two broad types of effects that changes of climate may have on agriculture; first effect on the geographical limits to the regions where different types of crops can be produced and secondly effects in the potential yields of crops in these regions. Increase in temperature can be expected to lengthen the growing season in areas where agricultural potential is currently limited by insufficient warmth.

Drought occurrences associated with climate change have become more pronounced in Kenya in the recent years with great blow on Agricultural productivity UNEP, (2007).Kenya has experienced a series of severe weather related phenomena particularly droughts, floods and Landslides (Murungaru, 2003).Droughts in Kenya are a common phenomenon where there has not been time to fully recover from one drought shock before another occurs Oxfam, (2006). Different parts of Kenya experience varied climatic conditions.

Plate 2:2: Maize crops that have been affected by the drought in Kenya

The crops that we grow for food need specific conditions to thrive, including the right amount of rainfall and temperature. A changing climate could have both positive and negative effects on crops. For example, the northern parts of the United States have generally cool temperatures, so warmer weather could help certain crops grow. In southern areas where temperatures are already hot, even more heat could hurt crop growth. Global climate change will also affect agriculture and food supply in many other ways.

Agricultural production in developing countries is rain dependent. Production cycles are therefore pegged on rain season. Maize production in many parts of Kenya is done in March and April at the onset of long rains. However in the last decade, the rainfall pattern has been inconsistent where the season sets in earlier than March or delays to later in April. The inconsistency across the crop cycle has resulted in drying up or poor grain formation particularly when rain in not sufficient at tussling stage. This reliance on rain-fed Agriculture is viewed by observers as making agriculture the most vulnerable economic sector with regard to climate variability.

According to Katz and Brown (1992), climate variability is likely to increase under global warming both in absolute and relative terms. According to reports of The Intergovernmental Panel on Climate Change (IPCC) Africa is vulnerable to weather variability due to a number of factors one being ecosystem degradation. Mt Elgon forest has undergone depletion due to logging effects of which is erratic rainfall patterns in most parts of Trans Nzoia and Bungoma Counties. In both counties, majority of the rural population is engaged in small scale Agriculture dominated by a single crop, mainly maize, thus, any instability on rainfall received it drastically affects their livelihoods as a decline in maize productivity would lead to food crisis given the single crop culture and the fact that maize is staple food to majority of the households. In addition, farmers' purchasing power is pegged on maize productivity; consequently even if there were supplies of food from other areas, they would not manage to pay for.

According to Mariara and Karanja (2006), the two extreme climate events that may adversely impact on the agricultural sector are drought (crop water stress leading to declining yields) and flooding (resulting in water logging) in both the ASALs and high potential areas. Climate change could make it too hot to grow certain crops, and droughts caused by climate change could reduce the amount of water available for irrigation. Climate change is also likely to cause stronger storms and more floods, which can damage crops. Higher temperatures and changing rainfall patterns could help some kinds of weeds and pests to spread to new areas.

2.9 Maize production in Trans-Nzoia

Trans-Nzoia County is a County in the former Rift Valley Province. The County is located between the River Nzoia and Mount Elgon. Kitale Town is the capital of Trans-Nzoia. The county borders Bungoma to the west, Uasin Gishu and Kakamega to the south, Elgeyo Marakwet to the east, West Pokot to the north and the Republic of Uganda to North West. Situated in the slopes of the Mount Elgon, Trans Nzoia County has a cool and temperate climate with average annual temperatures ranging between a minimum of 10°C to a maximum of 27°C. The county receives annual precipitation ranging between 1000 and 1200mm, with the wettest months being experienced between April and October during the Match, April, May (MAM) and October, November, December (OND) seasons respectively. This weather is favorable for maize growth.

Plate2: 3 : Picture showing maize that is well rainfed and about to be harvested

What comes to mind whenever Trans-Nzoia County is mentioned? Even before the term County came into being, Trans-Nzoia was already known. The region is known for one thing, maize. The county is largely agricultural with both large scale and small scale wheat, maize and dairy farming. The county is referred to as the basket of Kenya for its role in food production in the country. This is actually the County that to some extent determines the level of inflation in the country because it is one of the main producers of the country’s staple food.

Plate 2:4: Maize in one of the farms in Trans-Nzoia that is well rain fed

Trans-Nzoia County is arable land. This makes the practice of agriculture very efficient in the county. In this county, maize farming is widely practiced; maize is planted in both large scale as well as small scale farming. Almost 90 percent of farmers in this county plant maize for commercial purposes.

A wide range of investment opportunities exist in this county in the agricultural sector. Though many people have come to regard the maize farming as being unprofitable, the sector is an avenue to a world of investment opportunities. First, it should be noted that maize is actually the staple food of Kenya. When the price of maize flour goes up for instance, the country's inflation is shifted. This implies that maize is a very precious commodity to many households in Kenya and to the economy of the country in general. Maize farming can be frustrating in terms of losses to the farmer. This is because the prices of maize are never constant and they keep on fluctuating depending on the volume produced. However, for other investors, these are the opportunities presented by the maize farming in Trans-Nzoia County.

While warming may extend the margin of potential cropping and grazing in the region, it may reduce yield potential in the core areas of current production. "Maize production is expected to drop by 1.2 million bags this season due to poor rain patterns and of course due to other factors like the army worms. The county produces about 5 million bags annually from 100,000 hectares; she also disclosed that 50 percent of land translating to 53,000 hectares in the county has not been planted due to lack of rains" Nzomo (2017)

2.10 Case Studies

Agriculture is always vulnerable to unfavourable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, Weather and climate are still key factors in agricultural productivity. With the recent increase in price of maize flour and lack of its accessibility, rapid population growth and climate change and its impacts on food production there is need for use of advanced technology of geospatial technology to solve the climate change exertion and food shortage problem. The following case studies illustrate some example where the technology has been applied.

Bangladesh

In Bangladesh a number of simulation studies have been carried out to assess impacts of climate change and variability on rice productivity using the CERES-Rice model Julia et al, (2005). Effect of climate change on yield of two varieties of boro rice has been assessed using the DSSAT modelling system. The yield of BR3 and BR14 boro varieties for the years 2008, 2030, 2050 and 2070 has been simulated for 12 locations (districts) of Bangladesh. Available data on soil and hydrologic characteristics of the locations, and typical crop management practices for boro rice were used in the simulations. The weather data required for the model (daily maximum and minimum temperatures, daily solar radiation and daily precipitation) were generated for the selected years and for the selected locations using the regional climate model PRECIS.

The model predicted significant reduction in yield of both varieties of boro rice due to climate change; average yield reductions of over 20% and 50% have been predicted for both rice varieties for the years 2050 and 2070, respectively. The model simulations also suggested that changes in rainfall patterns may also adversely affect rice yield.

Simulation results also suggested that planting dates could significantly affect rice yield, and this effect could become more pronounced in the future.

Kenya

In Kenya a similar study was done by Wandaka et al (2013) the study analyzed the impact of climate change on maize production in Kenya using a Ricardian model. The data for this study was based on a sample of 1357 households. The data was sourced from Tegemeo Institute of Agricultural Policy and Development. The temperature data that was used in the study was from Satellite climate data while precipitation data was from ARTES (African Rainfall and Evaluation System). Soil data was sourced from the Kenya soil survey conducted by the Kenya Agricultural and Livestock Research Institute (KALRO). The general objective of the study was to conduct an assessment of the potential impact of climate change on maize production in Kenya

Five Global Circulation Models were used to produce ten scenarios that were used to analyse the impact of climate change on maize production in Kenya by the year 2100. The regressions results suggest that climate has a significant impact on maize production. Increase in March-May temperature and June-August precipitation was found to have an adverse impact on maize production while increase in March-May precipitation was found to have a positive impact. The results are in line with findings by Kabubo-Mariara and Karanja (2007), Kabara (2009) and Kabubo-Mariara (2009) who found out that climate change will have an adverse impact on agriculture in Kenya. The study found out that temperature has a bigger impact on maize production as compared to precipitation.

This is evidenced by the elasticity of temperature and precipitation. This result supports findings by Kabubo-Mariara and Karanja (2007) and Kabara (2009) who found a larger elasticity for temperature than for precipitation indicating that agriculture in Kenya is more sensitize to temperature than precipitation. Simulations from the climate scenarios indicate that maize production could fall by up to 23% by the year 2100. ECHAM scenario paints the bleakest picture, predicting that maize production could fall by 23% by the year 2100. Overall, all scenarios indicate a decrease in maize production by the year 2100. These results are in line with expectation that climate change will negatively affect agricultural production in Africa.

CHAPTER 3: METHODOLOGY

3.1 The study Area

Trans Nzoia County is one of the forty seven (47) counties in Kenya with latitude of: 1.019089 and longitude of: 35.002305 and it has three sub counties, namely Kitale, Kiminini and Endebesi. The county borders the Republic of Uganda to the West, Bungoma and Kakamega Counties to the South, West Pokot County to the North and Elgeyo Marakwet and Uasin Gishu Counties to the South East. It has a cool and temperate climate, with average annual temperatures of 10°C to 27°C. Precipitation ranges between 1000 and 1200mm, with the wettest seasons being experienced between April and October. Agriculture is the top economic activity, and maize farming is widely carried out, and mostly at commercial level.

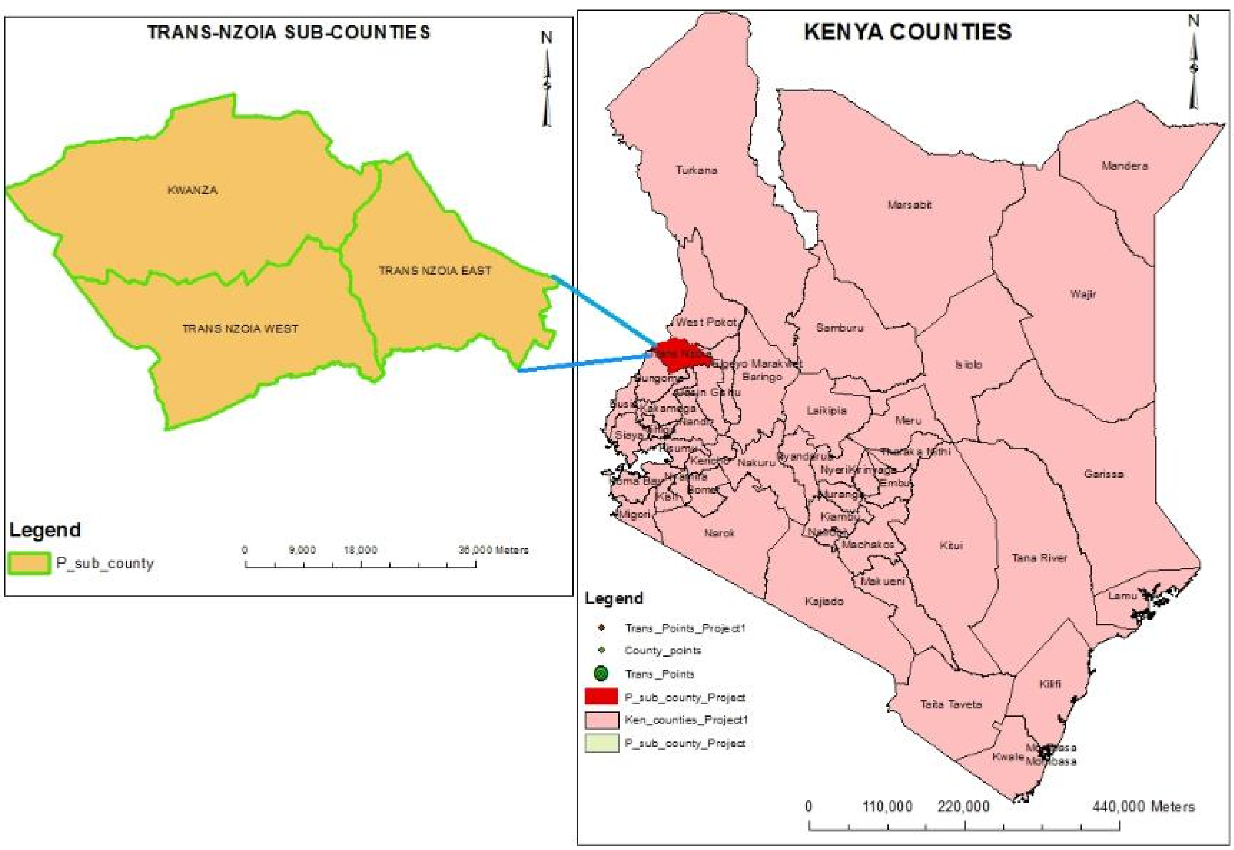

Figure 3:1: Map of the study area.

Table3. 1:Data sources and data sets

Data sets	**Data Description**	**Data sources**
County Shapefile	County Shapefile showing the sub-county boundaries,	KNBS
Maize data	Maize Production yield annually,	KALRO and DRSRS
Rainfall Data	Annual rainfall received in the county.	Trans-Nzoia Meteorological Department

Procedure in measuring spatial relationship between crop yield and rainfall total

Step 1; create the areal extent of the Trans-Nzoia sub-counties surface from existing Kenya county boundaries spatial data and project the resulting surface to UTM ZONE 38 N with a WGS 84 datum from geographic projection with WGS 94

Step 2; create crop yield from DRSRS crop yield survey spatial data 2007 to 2010 by first projecting the spatial data to UTM zone 36DATUM WGS 84 from geographic projection with Arc 1960 datum. Clipping projected data, crop yield data with the projected Trans-Nzoia surface data to come up with yield best fit.

Step 3; create a rainfall average spatial data from the global weather grid data by clipping it with the Trans-Nzoia surface area to create a best fit spatial rainfall data. Projected to UTM ZONE 36N DATUM WGS 84.

Step 4; Using the two best fit for crop yield and average total rainfall respectively , a Cokriging procedure based on probability distribution was used to create a prediction surface (interpolation) for both crop yield and rainfall spatial distribution.

Step 5; Assuming the crop yield spatial distribution grid was the independent variable, an ordinary least squares regression procedure was executed resulting in the following outputs:

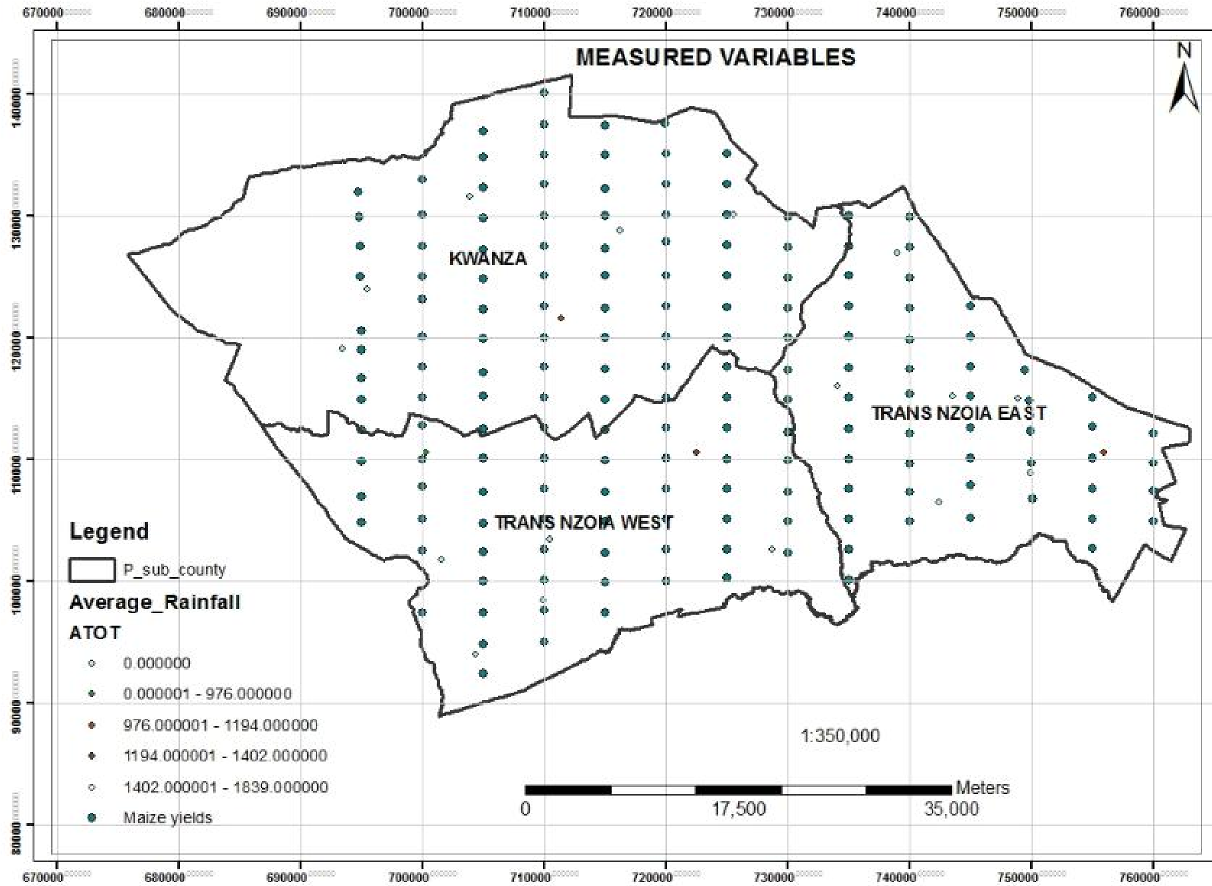

Figure 3.2: Area of study with the variables to be mapped.

3.2 Analysis methodology

The study used a surface modeling methodology using the Geostatistical analyst tool in Arc GIS which has interactive tools to visually investigate data prior to analysis. These tools allowed investigation and distribution of data, visualization of the spatial correlation within and between datasets, creation of surfaces from sample data by interpolation methods, evaluation of how the model performs and look for systematic trends in the data. Data that was collected from various agricultural institutions and the National Cereals Board for the county revealed the previous and current production levels of maize in Trans-Nzoia County. Rainfall data from the meteorological department starting from 1972 to 1982, 1992, 2012 was analyzed to look for systematic trends of the changes over the years.

Figure 3.3: Methodology flow chart

CHAPTER 4: RESULTS AND ANALYSIS OF THE RESULTS

Annual Maize yields and rainfall were plotted against the years and their spatial trends were as shown in the figure below**.**

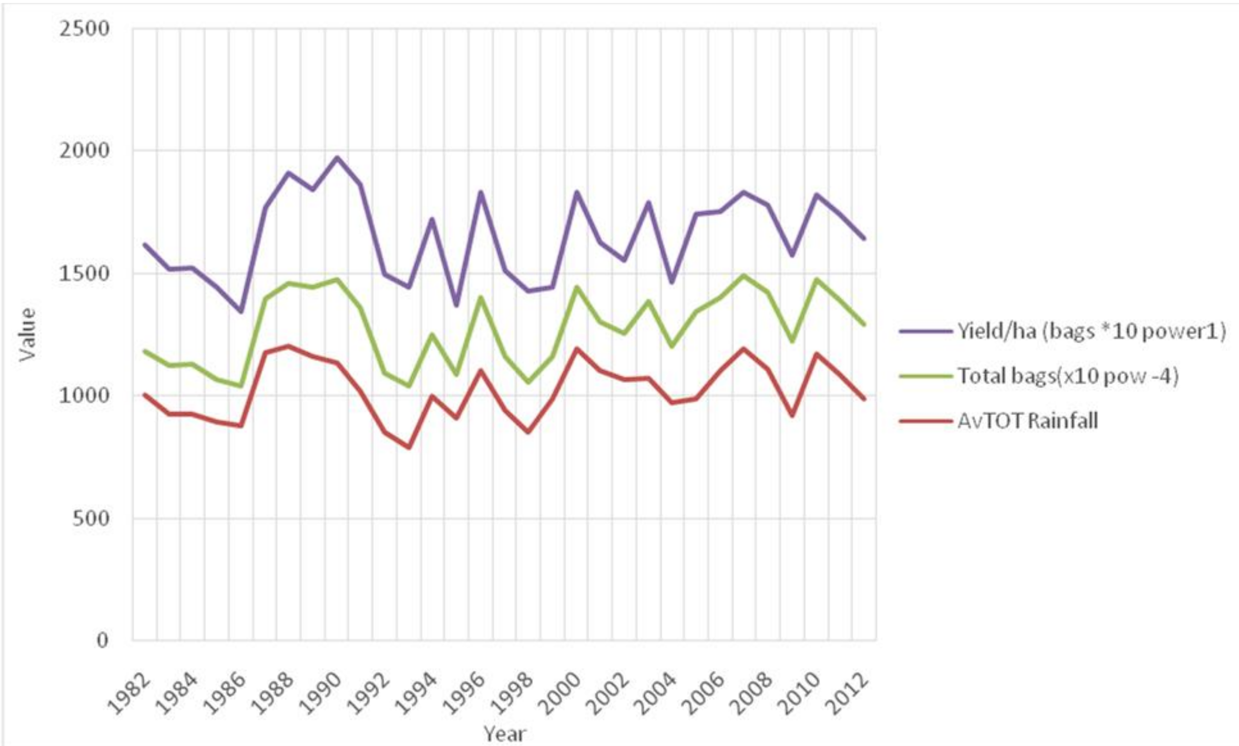

Figure 4.1: Maize and rainfall trend analysis over the years in Trans-Nzoia

There has been a slight increase of Maize yields over the years as shown in the figure above. The highest yield of 4.2 tons/ha was recorded in the year 2011 and there was also a slight increase in the rainfall received in that period, the lowest yield of maize was 1.8 tons/ha in 2007 with decreased rainfall as shown.

4.1 Test of Normality – Normal Distribution of Data

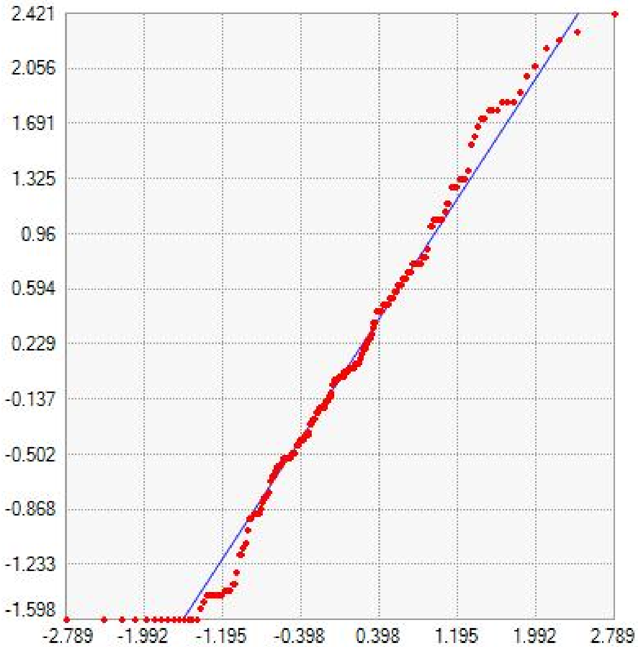

Figure 4.2: Normal plot Graph

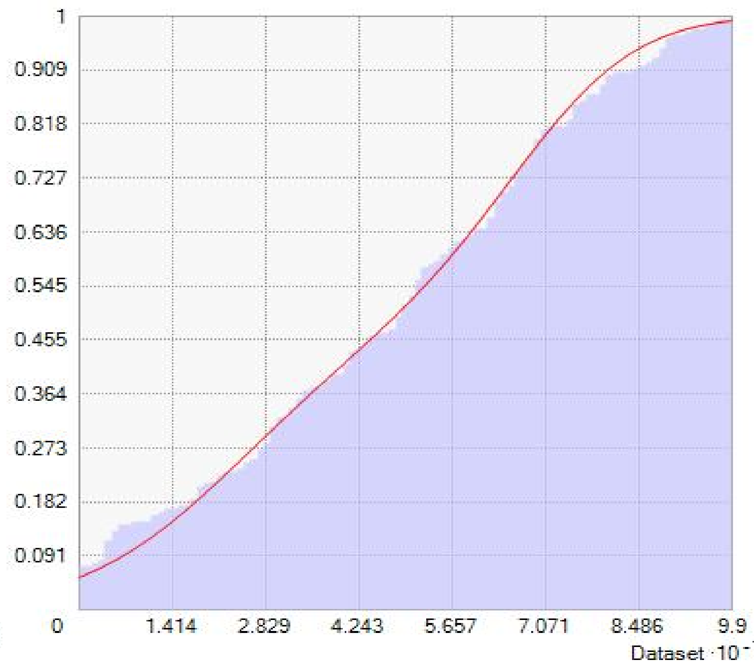

Figure 4.3: General Plot Graph

Maize yields and rainfall were found to be homogeneous as shown in the two graphs above2 and 3 respectively. They were carried out as one of the requirements to assess whether the data is normally distributed and to explore whether the two data sets have similar distributions respectively.

4.2 Combined datasets explored

Mapping data was the first step in data exploration in order to understand more about the spatial phenomena that was analysed. Data exploration was done to look for obvious errors in the values that may drastically affect the output prediction surface, examine how the data was distributed, and look for global trends, directional influences, and others.

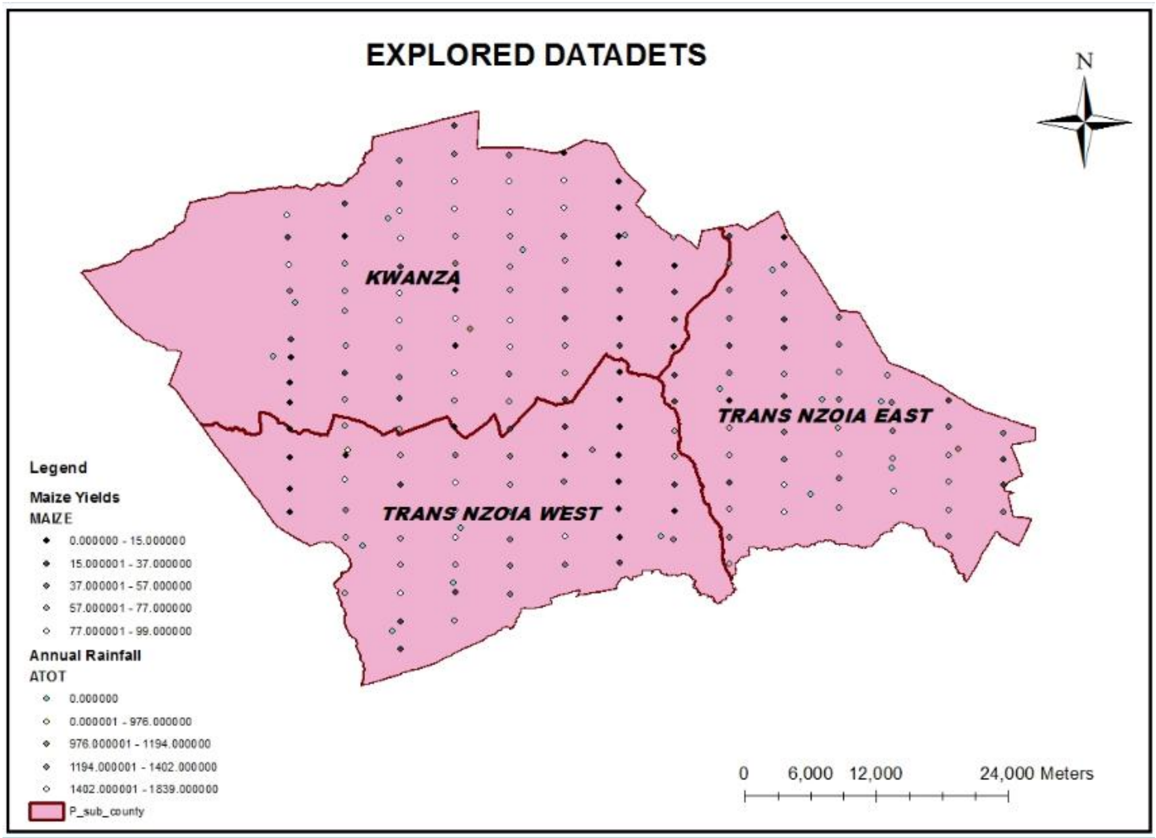

Figure 4.4: Datasets explored in Arc Gis

4.3 Rainfall Surface

A rainfall surface was generated using the Geostatistical analysis exercise of ArcGIS. Interpolation was done by using the rainfall point data as the input data and average total rainfall as the field data and kriging was used to interpolate the values at the location where they are known. The semivariogram/covariance displayed to examine the spatial relationship between the measured points. It allowed exploring the assumptions that, things that are closer together are more of the same than things that are far away from each other.

The crosshairs showed locations with no measured values. Values were predicted at the crosshairs, by using the values at the measured locations. Close measured locations were most alike in the deep red colours to the unmeasured values as shown in the map in figure 4.5. The red point in the image influenced unknown value since they were closer to the point predicted. The cross-validation diagram proposed how the model predicted the values at unknown locations.

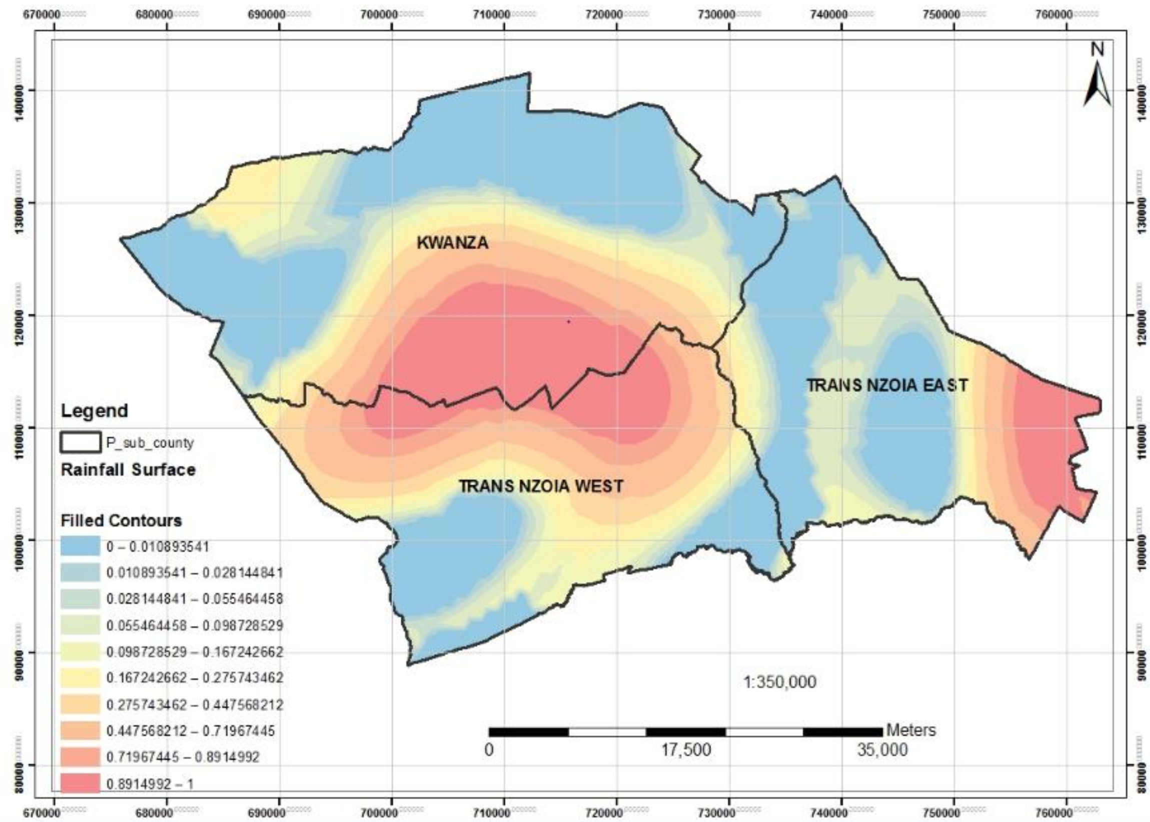

Figure 4.5:   Rainfall surface

The rainfall surface map above, showed contours filled with colours showing variations of rainfall amounts received and the area that received less rainfall. The locations showing deep red and dark orange indicated values greater than the yellow and blue colours as indicated in the legend. The highest area with the highest amounts of rainfall have the highest value as compared to less receiving. The rainfall surface map was clipped to display data within the borders of the study but area. Visually the Default Kriging layer presented the mapped phenomena.

4.4 Maize production yield Surface

Maize yield Interpolation was done using the maize yield point data as the input data and maize as the field data and Kriging has interpolation method. The semivariogram/covariance displayed for examination of the spatial relationship between the measured points.

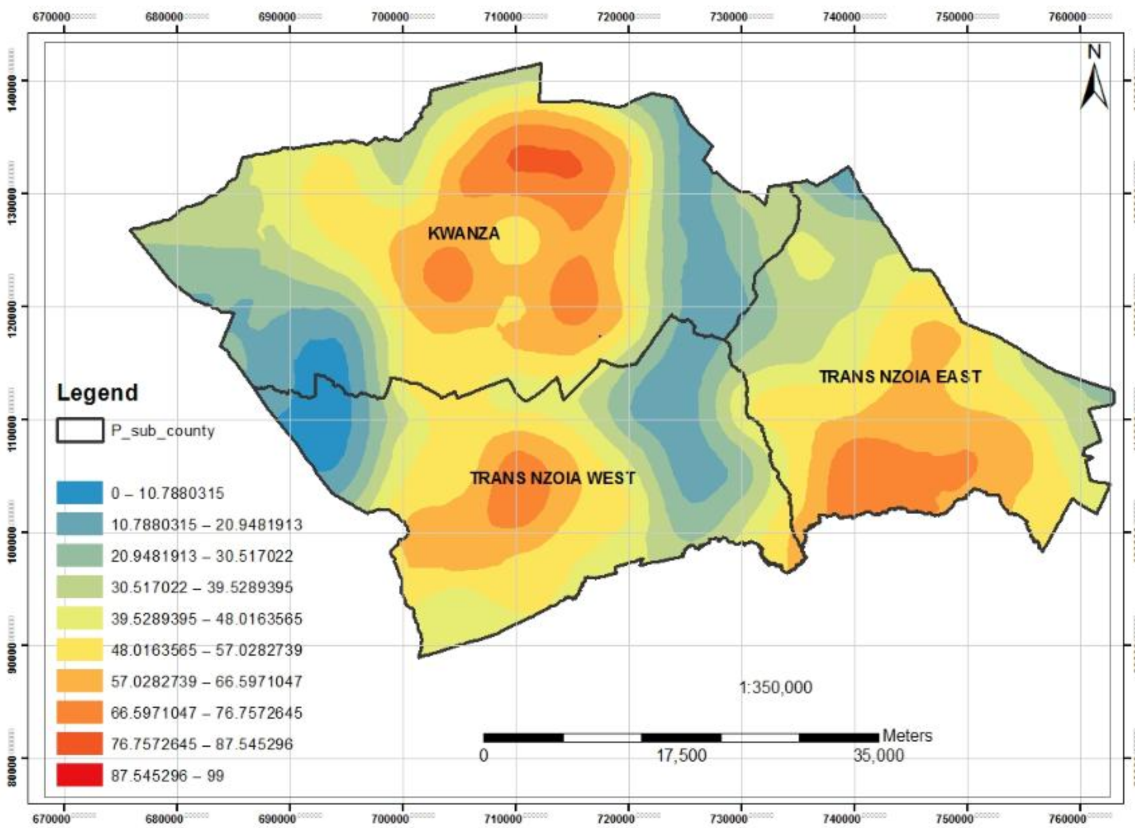

Figure4.6: Maize yield surface.

The semivariogram/covariance just like in rainfall surface, displayed to examine the spatial relationship between the measured points of maize yields. It allowed exploring the assumptions that, things that are closer together are more of the same than things that are far away from each other. The cross validation showed directional influence of the closest measured values since the locations were more alike to the value of the unmeasured location mapped. In figure 4.6 above results of maize production showed contours with high production in red and orange colour with figure 99% and the lowest with 20-10%.

4.5 Correlated surfaces/relationship generataed

It was evident from figure 4.6 below, that maize production in County and rainfall amount were significantly correlated. The amount of rainfall received annually (mm) with maize yield indicated almost 100% relationship.

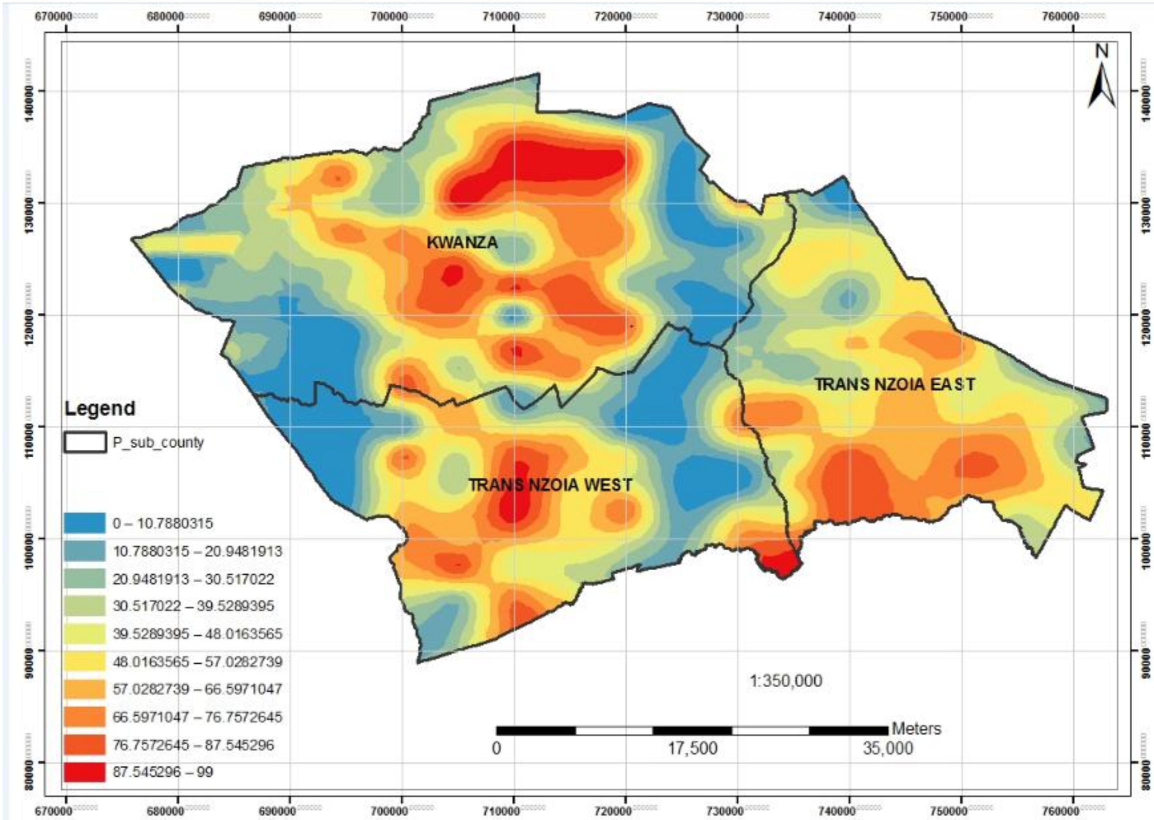

Figure 4.7: Correlated datasets/ Rainfall and maize yield

4.6 Prediction Model

The Relationship between Rainfall and Maize Production

The study sought to find out if there is any relationship between the dependent (maize production) and independent (rainfall) variables. From the results provided in table 4.1 indicates a model summary where it gave an R value of 0.334 and an adjusted R squared of 0.112. This is an indication that rainfall can only explain 11.2% of the production of maize, however the remaining percentage can be explained by other factors other than rainfall.

Table 4.1: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.334[a]	.112	.081	14499.34218

a. Predictors: (Constant), Rainfall

b. Dependent Variable: Maize

The ANOVA results given in Table 4.2 show a regression sum square of 767601222.201 and a mean square of 767601222.201. The table also provided a residual sum square of 6096696783.477 and mean square 210230923.568. With the F – statistics is 3.651 and P – values of 0.066, is an indication that we fail to reject the null hypothesis that rainfall can predict maize production as the error we make is more than 0.05.

Table 4.2: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	767601222.201	1	767601222.201	3.651	.066[b]
	Residual	6096696783.477	29	210230923.568		
	Total	6864298005.677	30			

a. Dependent Variable: Maize

b. Predictors: (Constant), Rainfall

The results indicated in table 4.3 show the coefficient value of rainfall to be 0.334 with a constant value of 26997.595.

Table 4.3: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	26997.595	23558.865		1.146	.261
	Rainfall	43.713	22.876	.334	1.911	.066

a. Dependent Variable: Maize

Analysis of the Results

Both datasets were analyzed by use of Geostatistical analysis and SPSS was used to generate a model for maize production. The Geostatistical analysis was used mainly to generate spatial surfaces maps for both maize production yield and annual rainfall received over the years which showed contours with the pattern in line with the objective. To establish the changing rainfall patterns and how its changing patterns are affecting maize production yields over time. Kriging method in the Geostatistical analysis was used. This is because it allowed the establishment of confidence that there is a relationship between the two variables spatially.

Semivariogram/covariance

The goal for a semivariogram model was to determine the best fit for a model that will pass through the points Semivariogram was used as a graphic representation to provide a picture of the spatial correlation in the datasets. The color scales presented values of each contour coded with lower values in blue and yellow while higher values were coded in red and orange respectively. Generally high production yield occurred where there was highest concentration of the two colors representing the higher values.

Cross-validation

The objective of cross-validation was to help make an informed decision about which model provided the most accurate predictions, how well the model predicted the unknown value by omitting a point in the dataset an finally the statistics calculated on the prediction error served as a diagnostic that indicated whether the model was reasonable for decision making. The surfaces with the highest value indicated higher production than the bluish regions.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objectives of this study were:

- To establish the rainfall trend in Trans-Nzoia between 1982 and 2012 at four year intervals
- To establish the corresponding maize production trend in the county
- To correlate the maize production data and rainfall data.

These have been achieved, and it is concluded that:

- Geostatistical analysis has provided tools that have made optimal predictions between the two surfaces generated and it has examined the relationships that exist between the two data sets.

- Delayed long rains throughout growth stages, will lead to poor yields due to wilting and dying of the maize crop leading to reduced yields.

- After correlating the datasets a prediction model was developed, which showed that rainfall had a small implication to maize production , this was so because, of the error term and that there are other factors that do affect maize production other than rainfall.

5.2 Recommendations

From the study, it is recommended that:

- Further studies be carried out on the influence of rainfall at critical stages of maize growth, and also on the influence of other factors such as temperature, pests, diseases etc.
- Important agricultural yield data be archived and safeguarded; such data should refer to all administrative units, from the smallest to the national level.
- I recommend that the farmers of Trans-Nzoia should be encouraged to grow fast growing and water resistant crops in order to have an extra alternative over maize farming.

REFERENCES

1. Aiguo, D. (2007 Advanced Review, *Drought under global warming*: Volume 2, Chinese National Meteorological Administration.

2. a.Basak, A (2010). Assessment of the effects of climate on, *Journal of civil Engineering*, pp 38, 95,108

   b. Biket, (2017) *Personal communication*, with the officers in charge, National Cereals board, Kitale

3. Climate Change Scenarios for the Netherlands (2006) *Scientific Report*,

4. a.David Suzuki Foundation and Staff, (2016) Climate Change and Greenhouse gases, *Annual report developed to inform science policy*, Canada, UK.

5. b.Department, K. M. (2017, March 23). *http://www.climatechangenews.com.* May 24, 2017, from http://sumo.ly/xzQ7 via @ClimateHome.

6. c.Dore, H. (2005). Climate change and changes in global precipitation patterns:. *Science Direct* , 1167 – 1181.

7. d.Dunbar, B. (2015) Climate change. *National Aeronotucs and Space Administration Officials,*Washngton D.C, .U.S.A.

8. e. Dr. Murungaru, (2003), *Kenya's* status Of *Drought Preparedness*, Kenya National Assembly Official Record (Hansard), Magazine.

9. Funk, *et al* Brown, M.E, (2009). Declining global per capita agricultural production and warming oceans threaten food security: *Food Security*, 271–289.

10. a. Government of Kenya, (2011) *A statement made public by the Minister of Environment and natural resources.*

11. b. Gregory, S. (2013) Economic analysis of the impacts of climate change on agriculture in Russia. *Cowley Oxfam GB* for Oxfam international.

12. c. Gregory. (2005). *Climate change and food security* Canada published online.

13. d. Guide, S. (2016).*Global climate change*: Environmental Protection Agency, USA

14. Interior, U. D. (2010). *A Climate Trend Analysis of Kenya*. USA: Rolla and Denver Publishing Service Centers.

15. a. Kabubo, M. (2007) Ricardian approach: The economic impact of climate change on Kenyan crop agriculture**,** *Global and planetary Change journal*, Vol 57, no. 3 pp. 319-330

16. b. Kartz And Brown (1992) Extreme Events In A Changing Climate, *Environmental And Societal Impacts Group*, National Center For Atmospheric Research Boulder, Co 80307, U.S.A.

17. c. Karanja, M. (2006) *The Economic Impact of Climate Change on Kenyan Crop Agriculture*: Policy Research Working Paper, pp 4334.

18. London Meteorological office (2017) *Annual reports on climate change.*

19. a.Manana, N. (2014). Challenges faced in the management of small scale farm. *international journal* , 945-950.

20. b. Mc Sweeney, (2008) Climate change and Eastern Africa *Journal of Climate*, Vol.4, No.2, pp 110-132.

21. a. Nation (2017) The statement picked from the Kenyan Daily news paper on Maize shortage in Kenya

22. b.Nelson, W. (2009). Impacts on Agriculture and costs of adaptation. *Climate change.* Washington D.C.

23. c.Nzomo, M. (2017 , May Monday). Maize production in Trans Nzoia to drop by 1.2 million bags.

24. Pachauri, R.K. (2007) Climate change, *fourth assessment report of the intergovernmental panel on climate change*, (2007), Geneva, Switzerland, p104

25. Roshydromet, (2011) Expert team on satellite systems *Federal Service for Hydrometeorology and Environmental Monitoring*, sixth session, Geneva, Switzerland.

26. a. Samuel, M. (2017) Climate change vulnerability and impacts analysis in Kenya, *American Journal of Climate change*, Volume, 6 No.

27. b.Slingo, J. M. (2005). Food crops in a changing climate. UK: The University of Reading, Earley Gate, Reading RG2 6AR.

28. Teng, S. (2015). Impacts of Climate change on food production: *Options for importing counties*. Policy Brief , Nangay technological University

29. Department of National Climate Assessment Report (2017) USA.

30. a. Wandaka et al (2013) The economic impact of climate change on maize production in Kenya, *Research paper* s*ubmitted for Masters Degree award*, University of Nairobi

31. b. Websites:

- http://observer.com/2010/04/how-soon-can-you-see-green-from-building-green/.Website: *www.epa.gov/climate-indicators Student's* Guide to Global Climate Change.