ASSESSMENT OF *ZEA MAYS* (MAIZE) YIELD CHANGES IN RELATION TO WEATHER VARIABILITY IN TRANS NZOIA DISTRICT, WESTERN KENYA.

By

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A PROJECT SUBMITTED IN PART FULFILLMENT FOR THE DEGREE OF MASTER OF ARTS IN ENVIRONMENTAL PLANNING AND MANAGEMENT.

DECLARATION

This project is my original work and has not been presented for a Degree award in any other University

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(C/50/P/8257/2000)

This project has been submitted for examination with our approval as University Supervisors.

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DEDICATION

This project is dedicated to my father, the late Alloys Oduor Osure.
Your son got the best due to your efforts. And to my Mum (Dorcas Oduor) for her passion to see me through college thereafter. Last but not least, to my lovely wife, Charity, brother (Roy) and sisters (Jacky, Vicky, and Meg) for their patience and understanding as I labored on day in day out.

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Let me single out Tom Ouna and all my classmates for their encouraging words and Charity for reading the draft and correcting all she could. Also thanks to Dr. Ogutu of International Livestock Research Institute (ILRI) for his valuable input.

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To all those who helped but due to my oversight I have omitted their names, just know that I am grateful. However, for any errors and omissions, I take full responsibility.

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ABSTRACT

Given the consensus of scientific evidence, the 21st century society will need to learn to mitigate, adopt and cope with accelerated weather variation and possibility of climate change. East Africa's livelihood systems, which are highly agricultural dependent, are likely to have to respond to climate variability and frequency of extreme events, including floods and drought. Thus, the first objective will be to understand the overall interactions between climate variability and yield responses.

The study thus aimed at assessing maize yield changes in relation to weather variability in Trans Nzoia district, Rift Valley province of Kenya. This was due to the area being one of the leading zones in maize production in Kenya. The study made use of daily temperature and rainfall data from the Metrological station for the period 1985-1996 and agricultural data from Rift Valley Province annual agricultural reports from 1985 to 1996.

The data was converted from daily readings to monthly and yearly means then subjected to several descriptive statistical techniques namely mean, standard deviation, variance, kurtosis, skew ness and time series analysis which revealed the occurrence of maize yield changes and weather variation in the area of study. Rainfall showed a stronger relation to maize yield changes than temperature according to the regression and correlation analysis with a combination of both variables accounting to over 50% of the yields attained

It was realized that there is a need to develop a regional climate change models that can be used to project country and provincial level climate change scenarios. The perspective deduced from ttie study was that a temperature increment of 1 degree Celsius for East Africa as projected by global climate change model will have little impact on maize yields in the highlands. This is due to the mean growing season temperature leveling at almost 18 degrees Celsius hence an

increase of one degree will still be in the maize temperature threshold thus cause little or no impacts on maize yields in these regions. However, an accompanied change in rainfall will definitely cause a change in maize yields.

CHAPTER ONE

1.0. INTRODUCTION

In East and Central Africa, there is no doubt that maize is the most important crop. In Kenya, maize is the most important food grain and plays a crucial role in the economic and nutritional needs of the people. The food crop ranks highest in land utilization as it occupies 23 per cent of the total area under cultivation. The total value of production, based on producer prices, is estimated at some Kshs 3.7 billion annually, and ranks highest in value among crops. The much talked about coffee takes second position valued at Kshs 2.1 billion annually (Muhoho, 1989).

In a nutshell, maize is the most important source of both income and subsistence for the rural population as nearly 1.5 million households in the rural areas of which more than 90 per cent are smallholders grow it. (Odok, 1991). Hence any changes in the output would inevitably have a major impact on overall national development. The importance of maize in this region cannot, therefore, be underestimated. However, there appears to be variations in the yields attained from year to year. For example, since 1997 to the year 2000, the production in 90 kilograms million bags, has varied from 4.31 to 4.85 and went as low as 3.53 in 1999, in Nyanza region. (GOK 1997, 1998, 1999, and 2000)

Agricultural production in general and maize production in particular depends on natural factors, mainly climate and soils; capital inputs; and human resources. However, climate is the £>verriding factor. (Awuor and Ogola, 1997). The dependence of agriculture on donate implies that conditions of temperature and rainfall, especially in rain fed agriculture, among other climatic factors, dictate the performance of both crops and livestock. As observed by Wangati (1984), climate and weather are major factors in agricultural production in tropical Africa where water availability is the principal determinant of both growing season and yield. Rainfall is a major climatic element in eastern Africa and therefore significantly impacts the socio-economic well being of the population who depend on rain-fed agriculture. Climate determines the type of crops the farmer can grow while individual weather elements such as light, rainfall, and temperature have direct effect on physiological processes such as photosynthesis, leaf expansion, as well as plant growth and development. Besides determining the daily programme of a farmer, weather also controls the spread of fungal diseases, insect pests and weeds, which can affect crop growth. (Awuor and Ogola, 1997).

Based on all these broad factors, the primary focus of agricultural research remains that of providing the means to increase per capita production. In the last two decades however, additional dimensions have been added to the research agenda by the increasing emphasis placed on sustainability agenda of farming practices and increasing threats of global climate change. (Lynam and Herdt, 1989). Although the sustainability agenda has a very broad content, embracing in some definitions, environmental and resource conservation, economic viability and the quality of life and human equity, its fundamental core rests on the ability to maintain or improve production trends over time. (Spencer and Swift, 1992, Isaac and Swift, 1993). Hence the need to understand effects of current trends on production to enable the farmer and policy makers to extrapolate the future production levels based on expected changes in trend.

1 • 1. Statement of the Problem

Kenya, with over eighty per cent of the land being Arid and Semi-Arid (ASALs), is to a great extend an Agricultural country. Current arable land in Kenya is concentrated in the highlands of the Rift Valley, Central, Western, Nyanza and Eastern Provinces, (Awuor and Ogolla, 1997). Out of the 3.2 million hectares under major crops in Kenya, Maize occupies 23 per cent of the total and therefore, ranks highest in land utilization. (GOK, 1994)

Agriculture is the world's single largest employer and is probably the most weather-dependent of all human activities. A healthy Agricultural sector has been shown to be a requisite for sustained economic growth in most countries (Watson, 1996). Thus adequate supplies of affordable food are seen as essential for poverty alleviation and economic development. Climate and its variation have been and continue to be, the principle source of fluctuations in global food production, particularly in the semi-arid tropical and equatorial countries of the developing world.

Crop yield forecast models are being used to estimate the crop yield much before harvest. The anticipated climate variation due to greenhouse gas-induced global warming is, however, expected to alter temporal as well as spatial patterns of rainfall, temperature, humidity, radiation, wind among other elements, thus affecting Agricultural production. It is therefore important to study the effects of climatic fluctuations on maize which is a staple crop in the study area at the household level so that vulnerable groups that depend on agriculture benefit from research.

1.2. Objectives of the Study

1. To identify changes in maize farms and yields in the study region form 1985 to 1995.

2. Assess weather variability using rainfall and temperature as variables of study from 1985 to 1995.

3. To attribute changes in maize yield to weather variation, that is, to derive a relationship- between maize yield changes and weather variability.

1.3 Research Hypotheses

1. Ho. There have been no significant changes in maize farms and yields form 1985 to 1995 in Trans Nzoia district.

Hi. The alternative.

2. Ho.There has been no weather variability in trans Nzoia district to affect maize yields.

Hi. The alternative

3. Ho. A relationship between weather variation and maize yield changes cannot be derived.

Hi. The alternative

1.4. Study Area

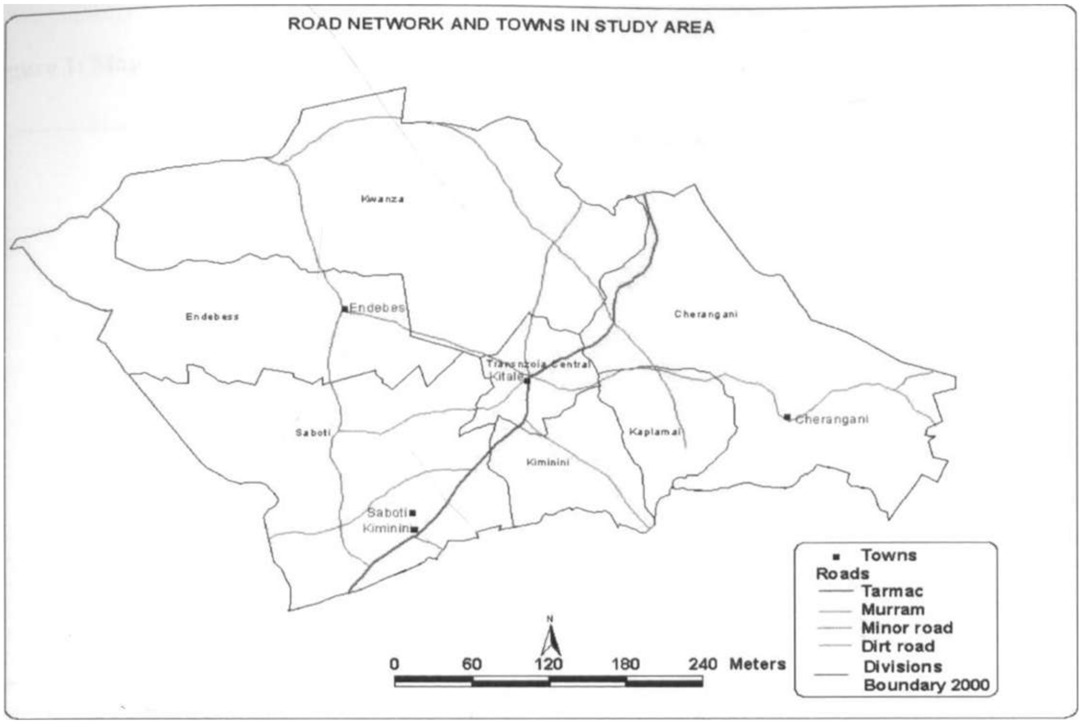
1.4.1. Introduction

Trans Nzoia is the smallest of the fourteen districts in the Rift Valley. The others are Baringo, Bomet, Elgeyo Marakwet, Kajiado, Kericho, Laikipia, Nakuru, Nandi, Narok, Samburu, Turukana, Uasin Gishu, and West Pokot. It covers an area of 2,468 square kilometers (246,000 Ha). This is 1.4% of the Rift Valley province and 0.42% of the country. It lies between latitude 1.025 and longitude 34.995.

It is situated in the North-West of Kenya bordering Uganda. It borders West Pokot district to the north, Marakwet to the North East, Uasin Gishu and Kakamega to the East and Southeast and Bungoma to the South.

Trans Nzoia comprises of four Agricultural Divisions, namely Cherengani, Saboti, Endebess and Kwanza Division. It has a population of 383,000 people comprising of about 36,000 farm families by 1987, a figure which grew to 569,000 people and 69,000 farm families by 1989 population census. The population has a growth rate of 4%.

Trans Nzoia is fairly staffed with technical staff that ensures that the appropriate messages get to the farmers and feedback from farmers gets to the researchers.



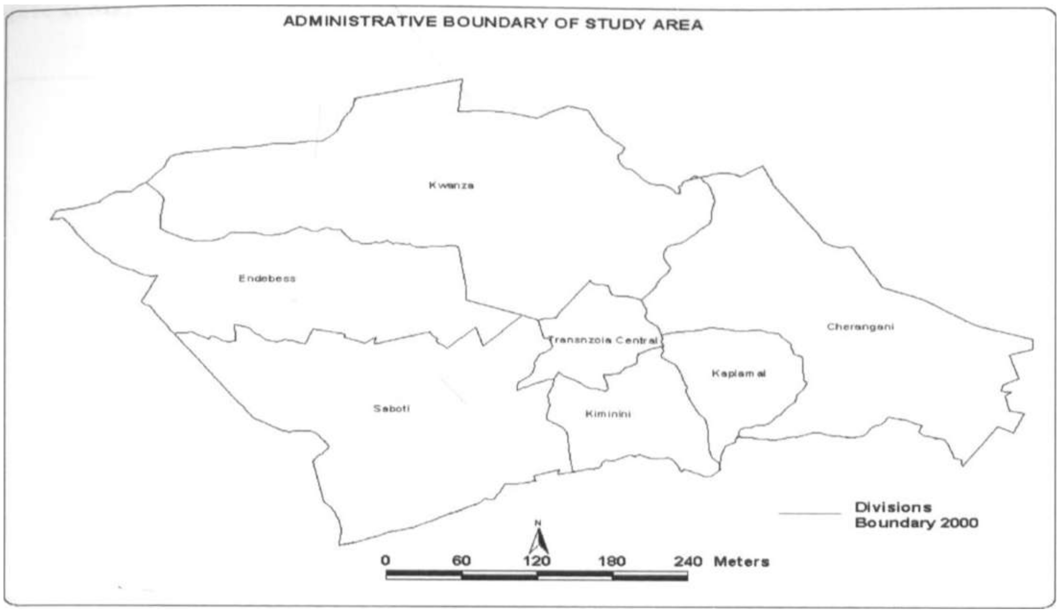
1.4.2. Relief

Situated at an altitude of 1890 meters above the sea level, Trans Nzoia district covers an area of 2,468 kilometers square. It is situated in the Rift Valley province of Kenya, bordering West Pokot to the North, Marakwet to the North East, Uasin Gishu and Kakamega to the East and South East and Bungoma to the South. There are several Lakes in the Rift Valley and the largest of them all being Lake Turkana, in the north-west of Kenya.

The District has an agricultural potential area of 1,486.1 kilometer square, which translates to over 80% of the total land size. Trans Nzoia is an extension of Uasin Gishu plateau and reaches over 2,150 meters in Cherengani hills. To the west of the district is Mount Elgon (4318m a.s.l) while to the East are the Cherengani hills (3,271m a.s.l)

Approximately- 80% of the District is arable (200,000Ha) with the rest being occupied by hills, mountains, rivers, swamps and Mount Elgon National Park.

Figure 1: **Map** showing divisions in **Study Area.**



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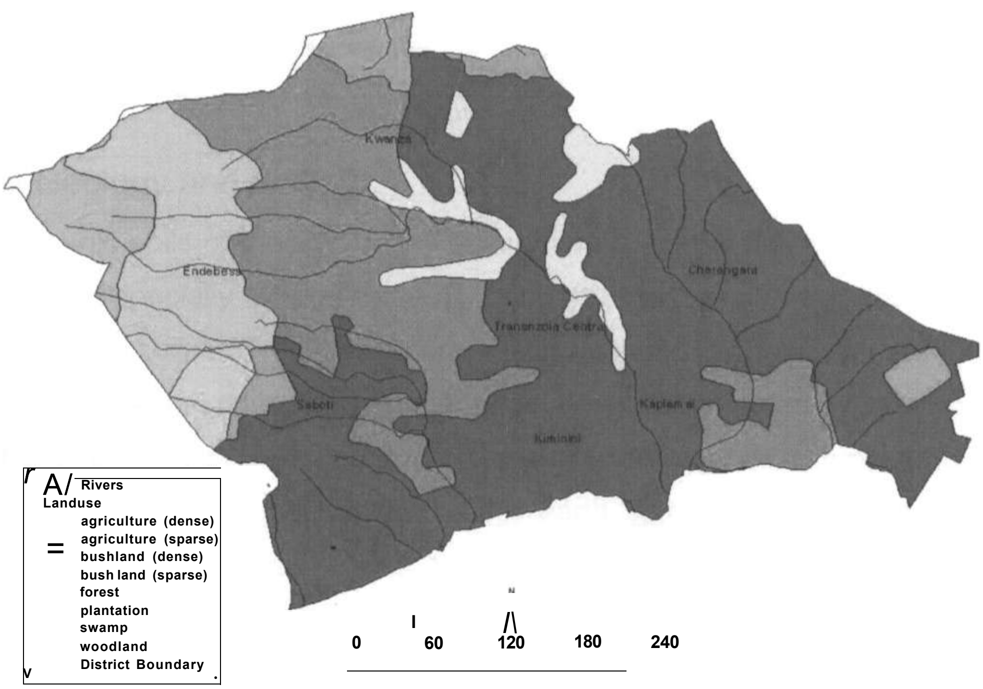
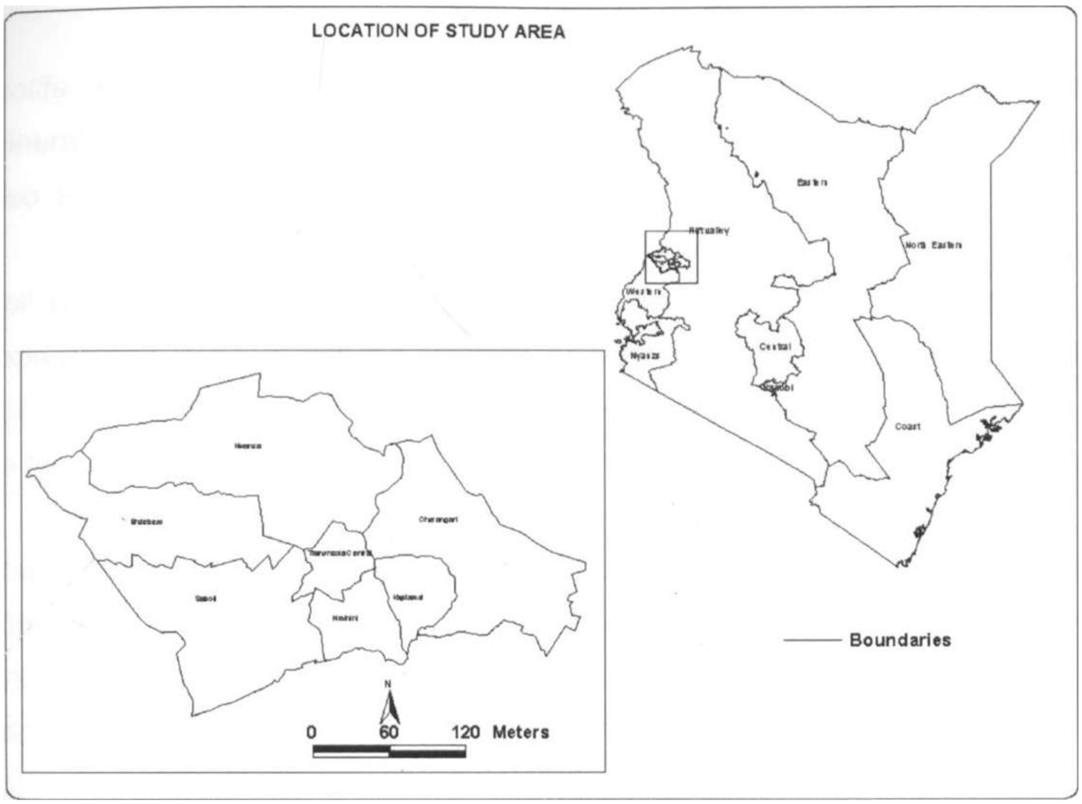


Figure 2: Map showing location of Study Area.



1.4.3.Geology and Soils

The volcanic soils of the Rift Valley is very fertile, and agricultural productivity is very high especially where there is good rainfall or at least good irrigation systems. The soils in Trans Nzoia are mainly volcanic in origin, and are therefore very rich. However, soils of any geographic region are affected by several factors usually acting in unison. These factors may be given as climate, the parent material, vegetation cover, nature of the earth surface, living organism in the earth and human activities.

The parent rflaterial is mostly important when considering the soil chemical composition, soil color, and distribution. Vegetation cover affects the chemical and biological composition and the age of the soil in terms of erosion. The nature of the land surface affects the soil drainage, distribution and maturity. The living organisms and human activities are mostly important when considering soil as a living body and in terms of soil conservation.

Biotite gneisses dominate the plateau with *gneisses* rich in ferro-magnesian minerals. This gives rise to very deep *rhodic ferrasols* and deep *orthic luvisols* also occur in areas around Cherengani.

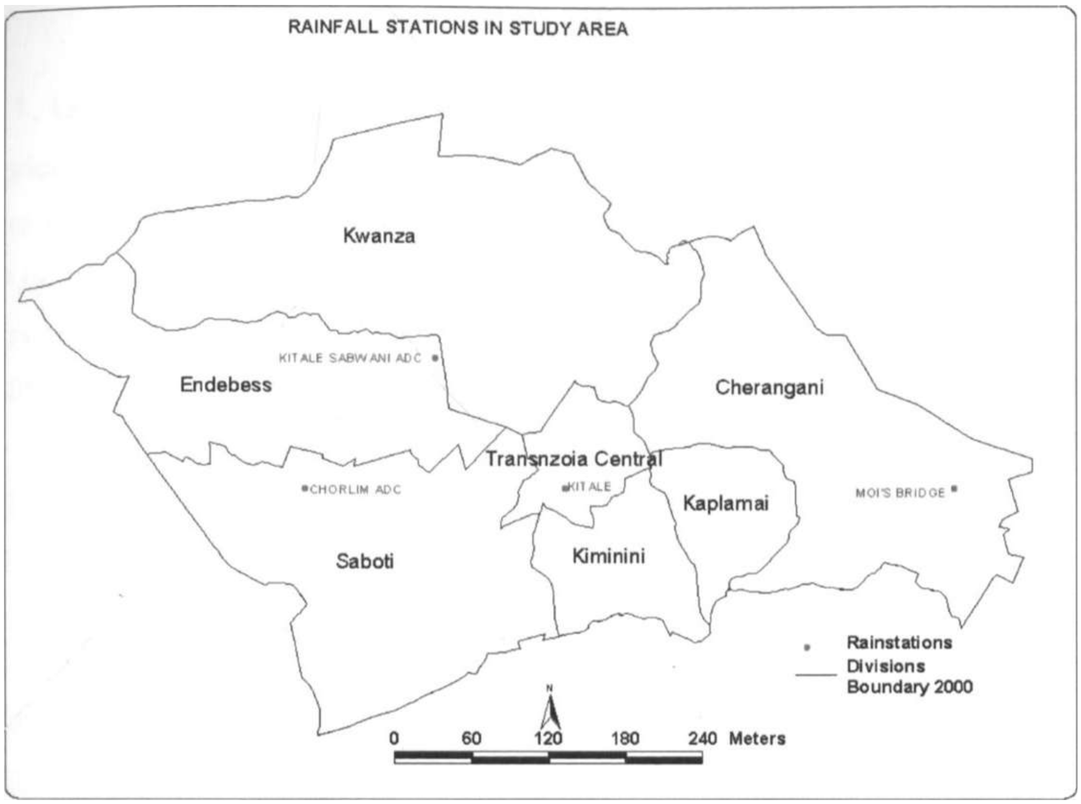
Soil type affect the soil water balance in terms of albedo, moisture retention capacity and moisture carrying capacity. This therefore affects the potential of the soils, which in turn may determine the type of land use and vegetation cover to be found in an area.

These favorable conditions leave Trans Nzoia as Kenya's leading district in commercial and seed maize production. However, wheat, beans, and sunflower are also grown. Livestock enterprises in the district include dairy, sheep, goat and poultry rearing.

1.4.4. Rainfall

In Kenya, the most important element of climate is rainfall and the main rain-generating systems are associated with the passage of the Inter Tropical Convergence Zone (ITCZ). Other factors affecting climatology of rainfall in Kenya are topography (altitude mostly), inland lakes, Indian Ocean, the Trade Winds (south East and North East), Egyptian air mass and the Congo (Zaire) air mass.

Trans Nzoia district has an highland type of climate with an annual average rainfall of 1000-1200mm. The rainy season (peaks in April and July/August) form one continuous agro-humid period from March to November/December. Second rains start indistinctly at the end of June/beginning of July. Mean annual temperature averages 19.4-17.9 degrees centigrade. Kitale is cool due to the altitude factor. Evaporation varies from 1650mm. Relative humidity is high throughout the year.



1.4.5. Land Tenure

Kenya has a varied land tenure systems ranging from freehold to communal ownership. In urban centers, land ownership is on a leasehold basis. The farm sizes have been declining due to sub-division creating small uneconomic plots. Kenyan rural areas are characterized by limited employment opportunities, low incomes and high incidence of poverty. There are on-going agricultural reform programs geared towards a liberalized agricultural sector. These programs are, however, hampered by poor support services which include access roads, markets centers and credit facilities among others. Currently there are two major strategies for promoting rural development. These include the District Focus for rural Development and the Rural Urban Balance Strategy. (Rok, 1997)

CHAPTER TWO

2.0. LITERATURE REVIEW.

2.1. General Literature Review

Agriculture, broadly defined, as the cultivation of crops and raising livestock, is one of mans most important land activitiy. Out of the world's total land area of 13,041,713,000 ha, about 4,789,710,000 ha were, in 1991, devoted to agriculture. Cropland amounted to 1,441,423,000 ha while pasture took 3,357,292,000 ha. (WRI, 1994) Thus, by shear size of land involved, Agriculture is among the most extensive human activities. About 80 per cent of the global agricultural land-use is for crop production, which is responsible for 50-60 per cent of all the production from Agricultural land. (Awuor and Ogolla, 1997)

In order of importance, the leading maize producing countries of Eastern Africa are Kenya, Tanzania, Ethiopia and Uganda and those of southern Africa are Zimbabwe, Malawi, Zambia and Mozambique. These eight countries account for more than 90% of the maize area and production in the eastern and southern Africa region. (Gebrekidan, 1989) Nearly all the maize in the region is produced under rain fed conditions.

In Kenya, maize *(Zea mays.)* is the main staple food in the west region of the country. (Provincial annual reports Nyanza, 1980 and Western, 1993). With a total annual production of 2.5 million metric tones in Kenya, maize contributes approximately 75 per cent of total cereal consumption, 44 per cent of total energy needs and 32 per cent of total protein requirements in the country. Maize production also contributes significantly to employment. Some 860 million-man hours are spent on maize production annually, which is equivalent to 700 man-hours per hectare per year. (Muhoho, 1989) production occurs in both the low and highlands areas. Between 1980 and 1988, about one million hectares and half million hectares were put under maize production each year during the long and short rain seasons, respectively. (USAID, 1989) Farmers in west Kenya region have adapted to growing the hybrid seeds while a few farmers still prefer the local variety seeds. (Provincial annual report, Nyanza, 1980). In Kenya, a very large amount of *heterosis* was obtained with two very narrow base populations of a *Tuxpeno* derived at Kitale Station Maize and a high altitude flint collection (No. 573) from Ecuador. (Darrah et al, 1978 and Darrah, 1986). The population-cross yield of two elite broad base populations, KCBx KCE, was only 86 per cent of the population-cross yield of the very narrow base population, Kitale II (R11) c1x Ec573 (R12) C1 (Eberhart et al, 1973). However the most common maize hybrid has been identified as varieties H622, H625, H626, and H614 (NARS annual reports 1981).

Ideal climates for maize are those with mean temperatures above 15 degrees Celsius in frost-free areas. Variety are however, adaptable to varying climatic conditions, hence the spatial variation that exists in the length of the growing season. In areas with mean temperatures greater than 20 degrees Celsius, the crop takes between 80 to 110 days for the early maturing variety and 110 to 140 days for the medium variety. (FAO, 1979). Maize germinates best at temperatures about 18 degrees Celsius, with the monthly mean after emergence ranging between 23 to 28 degrees Celsius. Above the minimum temperature necessary for growth processes to occur, threshold temperature, an increase in temperature by 10 degrees has a doubling effect on the rate of life processes in the plant. The increase in the rate of life process continues until the delicate balance between the various reactions is upset, that is at the limiting maximum temperature. Further increase of temperature above the maximum becomes injurious and eventually the planfmay even be killed.

One of the major environmental factors to which plants respond is mineral nutrition. Plant nutrition has been defined as the supply and absorption of chemical elements necessary for growth and metabolism. According to Shuman in plant-environment interaction (1994), the positively identified essential plant elements include C, N, O, P, K, N, S, Ca, Fe, Mg, Mn, Cu, Zn, B, M, Na, and Cl.

There are many factors that have contributed to the poor performance of food production in Africa. Poor crop and animal husbandry, poor marketing facilities, lack of capital, psychological and sociological factors, poor tools and storage facilities, pests and diseases, fluctuation of commodity prices, aridity, competing land use and poor land tenure are some of these factors. Allan (1971), reports six agronomic factors affecting maize yield in western Kenya, ranked in order of importance as the time of planting, maize genotype, plant population, weed control, nitrogen and last but not least phosphates. Muhoho, 1989 states that first and foremost, there are too little irrigated land in Africa, with most African countries irrigating less than 5 per cent of the arable land. Without irrigation we cannot control one of the most important determinant production factor, soil moisture. The second sets of factors are of a policy nature. Distorted policies of low producer prices and low consumer prices for the politically articulate urban population is a disincentive to farmers. Thirdly, external factors exacerbate Africa's ability to feed itself. Africa frequently experiences natural disasters such as droughts that devastate crops, decimate large herds of livestock and dislocate human population. Occasional floods occur and migratory pests such as locusts and armyworms are an ever-present threat. The final aspect of external factors is the foreign debt. The astronomical external indebt ness has really constrained Africa's ability to develop its Agriculture.

2.2. Crop Related Literature

Agronomic research has been going on in Western Kenya since the introduction of maize by the white settlers about the year 1900. The results of this uncoordinated, non-continuous, scattered work by individuals were only available for use by the large-scale European farmers. However, systematic agronomic research started at Kitale in 1964, with the initial objective of determining the relative importance of six major agronomic factors known generally to affect maize yields.

Onyango and Mwania, 1988, argue that results of on-station fertilizer trials seldom reflect the situation in farmers field. Little or no response to high fertilizer rates occur in experiment station due mainly to high soil fertility statues coupled with good cultural practices while in farmers fields it is due to low fertility interacting with other poor cultural practices.

Centino et al, 1995, on impact of climate change on rice production in Asia states that the potential production of a crop is assumed to be determined solely by the intersection of genotypic characteristics with the solar radiation, temperature, carbon dioxide level, and day length that it experiences. Solar radiation provides the energy for the uptake of carbon dioxide in the photosynthetic process while temperature determines the crop growth duration, and the rates of physiological and morphological processes. Day length can affect the rate of development at certain phases of the crops life cycle, and to a lesser extent, the amount of solar radiation received by the crop. Crop models simulating potential production of rice, therefore, need solar radiation, temperature, and carbon dioxide level as inputs. For the simulation of rain fed rice systems, additional information on rainfall, humidity, wind speed, and the hydraulic characteristics of the soil is needed.

In countries such as Great Britain, where heavy reliance is placed on non-irrigated pasture as a feed source, it has been possible to forecast annual milk yield on a national basis by using spring production and June rainfall as predictors. (Smith, 1968). Curry (1962), related average dry matter production from averages of soil moisture as indicated by rainfall and rates of evapotranspiration. Long-term climate data were used to provide a probabilistic description of monthly pasture availability, and average seasonal programming of livestock-pasture relationship. Maunder (1970), related variation in butterfat production to rainfall conditions in individual summer months and estimated the financial value to New Zealand farmers of these weather generated differences in production levels.

Current attempts to predict the impacts of future climate variation on ecosystems involve reference to many different kinds of information. These sources vary in scale and focus from short-term studies of the response of particular species, to long-term monitoring of field plots. The climatic elements of rainfall and temperature influence the duration and rate of growth of rain fed pastures in Eastern N.S.W, a region where non-irrigated pastures form the greatest part of feed intake for dairy herds and where year round grazing is practiced. (Dragovich, 1980). The study concluded that in a grazing system, temperature or moisture conditions, which inhibit or prevent growth of pasture plants will reduce the short-term availability of herbage and, depending on the timing in relation to growth phases of different pasture types, stress periods may have adverse effects on the quality of forage present at a later date.

In recent years, a number of controlled environment studies have added to our understanding of the effect of increased temperature and carbon dioxide on the production of many crops. (Kimball, 1983; Acock and Allen, 1985). Interactions between these effects are very important; a temperature increase at higher latitudes, for example, in Central and Western Kenya will lead to gains from increased arable land due to such areas becoming more suitable for agriculture and increased multi-cropping. (Awuor and Ogolla,1987). In principle, temperature increase is likely to increase production in the potential Agricultural areas of Central, Western and some Coastal parts of Kenya, provided that there is a corresponding increase in precipitation. For the already stressed areas such as the ASALS of Kenya, however, any slight change in temperature is likely to have devastating effects on agriculture. There is likely to be a shift of productive agricultural regions towards the high altitude and also a shift in the type of crops currently grown in the hot lowlands of the country.

Eventually, some of the monitoring studies now in progress may be expected to provide the first direct evidence of vegetation response to global climate variations. For the present, however, their main use is to test the predictive value of existing scenario/ models. Year to year variation in climate at most locations is considerable and it seems reasonable to judge our capacity to extrapolate into the future from the accuracy with which recent or contemporary fluctuations in vegetation composition can be predicted from the climate record. (Grime et al, 1994)

Hudson, in Agronomic Implications of long-term weather forecasting, showed that the variation in total output of fruit and vegetables, was to some extent by changes in acreages, but at least part of the variation from year to year, as shown by the Ministry of Agriculture, Fisheries and Food, (Britain) were associated with particular aspects of the weather.

A study done to assess maize production and climate risk in Malawi identified as considerable the difficulties of quantity production risk, as well as the problems of identifying biophysically viable and socio-economically acceptable methods of ameliorating its effects." Some headway towards treating these problems can be made through the use of appropriate validated crop simulation models". Using CERES- maize to stimulate maize growth and yield, the study concluded that distribution of maize yields changes markedly depending on the start of the rains that is early, normal and late. Maize production in central Malawi is greatly affected by rainfall patterns. Simulation modeling is a tool that can be used to help quantify the risk included: simple analyses of rainfall records can be used to classify season types, allowing season specific management recommendation to be derived. The models can also perform regional analyses that take account of local differences in environmentaf conditions. (Thorton and Mac Robert, 1994)

V

Peter Jones and Philip Thornton (2003) in the paper' Scenario projects 10 percent drop in developing country maize production over the next 50 years. The researchers forecast possible annual losses of up to 10 million tones, enough grain to feed 140 million people. The findings are based on results from a computer model called MarkSim that simulates weather conditions at different locations based on data from weather stations worldwide.

It predicted that the decline in production will not be across the board or evenly spread. However, rising temperatures and shifting rainfall patterns will vary widely from one agro-ecosystem to another. In sub-Saharan Africa, the researches forecast that Nigeria, South Africa, and Tanzania will lose upwards of 20 percent of total production. The message to be derived from the data, however, is that there will be many places where yield reductions can be handled by new varieties or agricultural practices, some where yields will increase due to climate change, and still others where crops will effectively no longer grow. Thornton says that big picture projections available in the past often tend to hide the fact that the impacts of climate change on maize production could be disastrous for some resources poor households on the local level.

It therefore becomes important to understand the crop-environment interaction at broad levels in order to conceptualize expected changes in yields with different climate change scenarios.

2.3. Conceptual Model.

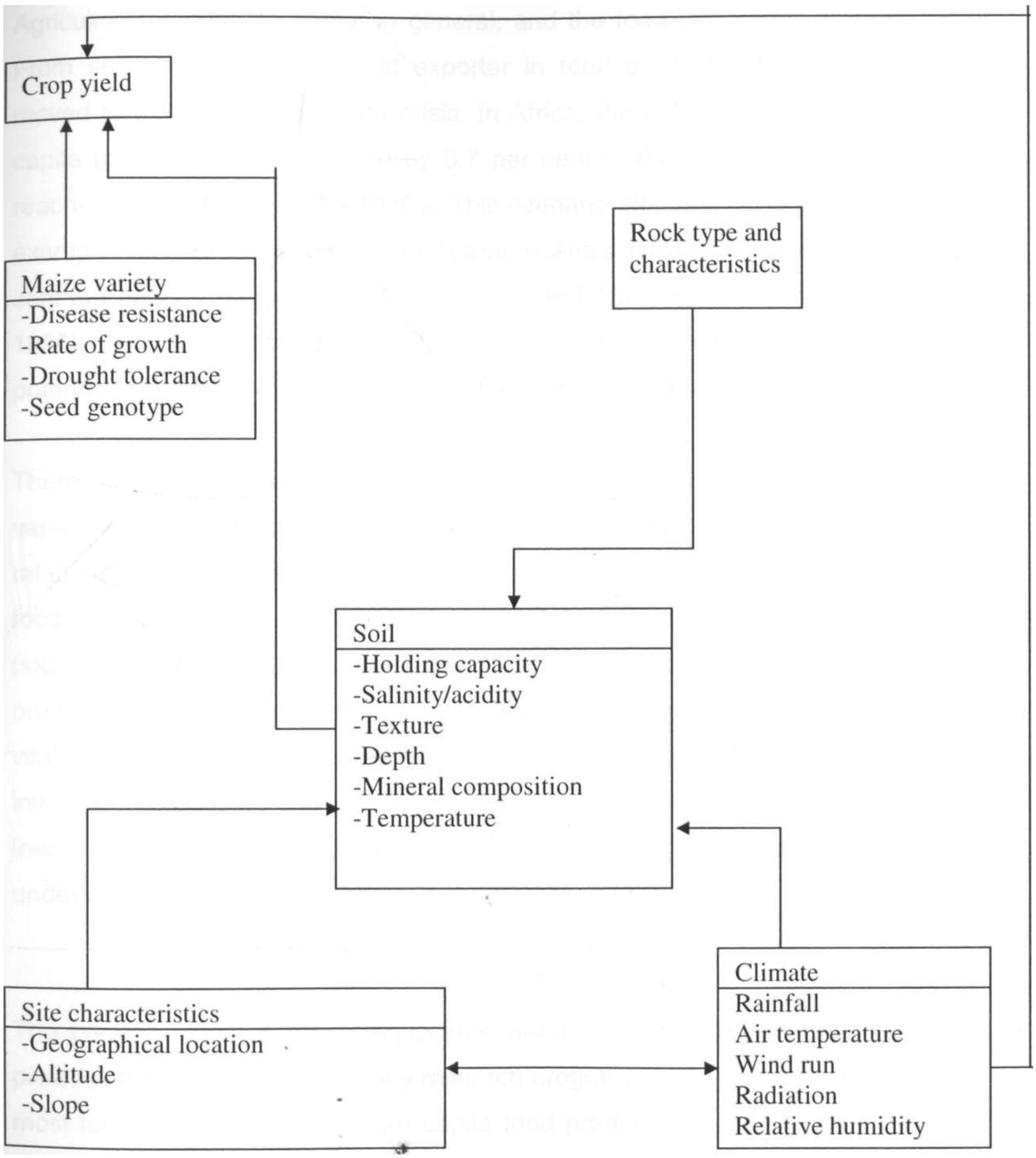
Crop environment interrelationship are complex since they incorporate both the biotic and the a biotic components which are by themselves interrelated (Ndolo, 1985, Musingi, 1990)

The success of any crop in terms of production is determined by many factors within the crop environment. A shift in any of the environment factors could mean failure in yield in spite of the other remaining favorable (Musingi, 1990).

In order to investigate the effects of variable in an environment, some factors have to be assumed to be favorable and constant. Although this may not be completely realistic, the approach has been found to explain a large part of the current variation in farmers yield from year to year. (Centeno et al 1995)

To accomplish the goals of this study, a conceptual model of the maize plant environment model was developed as shown in figure 1 below. The model components include maize variety, site characteristics, climate and atmospheric dynamics, soils and associated rocks, socio-cultural environment, agronomic activities, and fertilizer use. These components were considered in this study to affect maize yields in Trans Nzoia district in Kenya. The components included in this study were crop yields and climate variability as measured by temperature and rainfall. The crop yield was measured annually as was the rainfall and temperature conditions but in some cases, monthly data on temperature and rainfall were used to determine the nature of weather variations in the area.

Figure 4: Maize Plant Environment Model (Adopted from Musingi, 1990)



2.4. Justification of Study

It is on record that many countries in Africa have recorded dismal performance in Agricultural Economics sector in general, and the food sub-Sector in particular. From self-sufficiency and a net exporter in food products, the continent has moved to one of recurrent food crisis. In Africa, the annual growth rates of per capita food production declined by 0.7 per cent in the 1960's and the decline reached 1.25 per cent in the 1980's. This scenario affects a large population, for example 460 million people in Sub-Saharan Africa (SSA) and growing at 3 per cent per annum. (Muhoho, 1989) The Food and Agricultural Organization (FAO, 1996) has shown that collectively, African countries have at the moment the potential to feed 780 million people, thus all hope is not lost.

There is need, however, to understand the relationship among the many variables cited affecting Agriculture. This is further confounded by the relationship between expected climate variation and Agriculture, as the world's food production resources are already under pressure from a rapidly increasing population, 1 billion for Africa by the year 2010. Both land use patterns and the productivity of crops are likely to be affected. (Solomon and Leemans, 1990); it is vital, therefore, to obtain a good understanding, not only of the processes involved in producing changes in the climate, but also the nature and effect of these changes on crop growth, development and yield. Such studies begin by understanding the trend over time, hence the need for this study.

The present plight of Africa Agriculture needs no detailed analysis here, but provides the context for which any research programme should be designed. The most fundamental fact is that per capita food production in Sub-Saharan Africa (SSA) has continued to decline^bver the past two decades, at a time when an increasing trend has been observed in the rest of the world, including the other tropical regions. (Swift, M.J et al, 1994) Any research has to address this issue, which is rooted in the circumstances and characteristics of Africa Agricultural systems.

The climatic elements of rainfall and temperature influence the duration and rate of growth of rain-fed pastures. (Dragovich, 1980). Since maize grain production forms the most important crop in East and Central Africa, and contributes approximately 75 per cent of total cereal consumption in Kenya, at the household level, any risk and uncertainty can lead to substantial production instability with flow-on effects on income levels and food security. At the national level, Agricultural production instability can have enormous social and economic impacts affecting all sectors of society.

This research is the foundation of a rigorous science that will incorporate a strong element of model building and hypothesis testing using crop simulation models such as CERES-maize. There is, however, a particular need to distinguish between effects of temperature and moisture supply to crop yield and effects of other environmental, economic and management initiatives. Hence specific experiments, preferably manipulative experiments are essential to resolve these questions.

This study evaluates the effects of climate variation (rainfall and temperature) on the overall maize production in West Kenya in terms of the proportional effects on overall production. It is recognized that this approach has limitations in that it assumes weeds, diseases and insect pests are absent, there are no adverse soil conditions, and that no extreme^weather event such as floods, occur. Although this may not be completely realistic, the approach has been found to explain a 'arge part of the current variation in farmers yield from year to year due to weather. (Centeno et al, 1995).

CHAPTER THREE

3.0. RESEARCH METHODS

3.1. Types and sources of Data

The study was based on annual maize yield reports from the ministry of Agriculture in Trans Nzoia district of Rift Valley province. Other agricultural data included in the study were maize types, crop performance and actual planted area. These were sourced from the Kenya Agricultural Research Institute (KARI) headquarters data stores.

The weather variables included in the study were daily rainfall and temperature and these were obtained from the Metrological department headquarter in Dagoretti, Nairobi.

3.2. Data Collection

Since the single most important factor separating maize mega-environments in Eastern and Southern Africa is altitude, it was used in this study as a criterion for choosing the area of study. The following altitude definition is used to separate the mega-environments following CIMMYT'S classification in the "Maize production regions in developing countries"(CIMMYT, 1988):

Table 1:CIMMYT Maize mega-environments (1988)

Highlands	> 1800masl
Mid-altitudes	1000-1800masl
Lowlands	<1000masl

Each of these could be further divided using rainfall and temperature as criteria, •n Eastern Africa, the bulk of this zone is in the altitudinal zone of 1600-1800m.

Temperature and Rainfall data was retrieved from the computer stores at Dagoretti corner, Metrological Department headquarters, Nairobi. The weather stations identified due to their reliability of records were Kitale metrological station, AMS DAO, Elgon Downs and ADC Katuke. These weather stations were mapped and overlaid on the Provincial boundary map to show the spatial representation of various Agro-climatic zones.

Data on Agricultural performance come from annual provincial Agricultural reports as given by agricultural stations in Trans Nzoia district. Stations (weather and agricultural) from which the data come from were confined to Trans Nzoia district and represent nearly all the high altitude Agro-climatic zones.

3.3. Data Processing and Analysis.

The study area map was made by use of Geographic Information System (GIS) layers in Arc View. Several layers were mapped namely administrative boundaries, vegetation cover, Agro-Ecological Zones (AEZ), Maize yield, rainfall, rivers, roads and towns. This allowed ease of spatial analysis using several GIS software.

Maize yield data from the year 1985 to 1996 was collected from the actual hectares of maize planted and not the targeted hectors. This data was in tones per hectare and total production in 90 kg bags. For ease in statistical analysis however, yield tones per hectare was used.

The rainfall and Temperature data were collected on a daily basis. For the purpose of this study, these variables data were converted to monthly basis using statistical tools such as SPSS, SYSTAT and Microsoft Excel.

Using the growing season data, the initial analysis of the data involved the use of mean (X), which locates the center of the distribution. The formula used was:

$$X = \frac{I * .}{n}$$

A measure of central tendency, which locates the center of the distribution, should be complemented by a measure of the spread of the data. This spread was considered in term of how variable the data is in magnitude, that is, measures of variability. The most common measure of variability is variance, or the average squired deviation around the arithmetic mean, using the formula:

$$\frac{2 > i - *)^2}{n - l}$$

This was further emphasized by the calculation of Standard Deviation using the formula:

$$s = \bullet \frac{K_{i=1} * , - * >^2}{n - l}$$

The analysis of variance and standard deviation tests together with the descriptive statistics results gave the general tendency of the daily rainfall distribution over the period of study. However, need to assess weather variation called for a higher statistical analysis technique namely, the time series analysis.

A time series consists of observations taken at a specific time usually at equal intervals or simple observations arranged sequentially with respect to time. Mathematically a time series can be defined by values $yi, y_{2)} y3 \ldots y_n$ of a variable y (daily rainfall in the study).

Time series technique was the most appropriate method of analysis in case of time-dependant activities like daily rainfall in the study.

Time series has several components and these components suit best the study of natural fluctuations like daily rainfall time series. The components are:

- Trend: long time movement
- Cycles: fluctuations about the trend of greater or lesser regularity
- Seasonal fluctuations, which repeat themselves within, fixed periods of time less than one year.
- Random, residual or irregular fluctuations.

A time - series is therefore represented as a sum of (additive model) or product of (multiplicative model) the above four components namely, Y=T+C+S+L or Y=TCSL where :

T-trend

C-cycle

S-seasonal effects

I-irregular or random effects.

Linear regression analysis was used to develop the equation to describe the relationship between the maize yield ratio and the assessed weather variation if any. This procedure enabled the quantification of the effects of weather variation on maize yield in the 'absence' of other agricultural limitations.

Correlation tool was used to determine whether there was a relationship among rainfall, temperature and yield data. This determined whether the correlation was positive, that is, if the large values of one set are associated with large values of the other, or negative, that is, whether small values of one set are associated with large values of the other or whether values in both or all sets were unrelated (correlation near zero).

3.4. Limitations.

It is recognized that this approach has its own limitations. First and foremost, the use of secondary data as was used in this study can never be certified by the author as accurate. External factors such as fertilizer use and farming methods, which are important in large scale farming were not inco-operated in this study. The study's approach also assumes weeds, diseases and insect pests are absent, there are no adverse soil conditions, and that no extreme weather event such as floods, occur. Although this may not be completely realistic, the approach has been found to explain a large part of the current variation in farmers yield from year to year due to weather. (Centeno et al, 1995).

CHAPTER FOUR

4.0. Results and Discussions

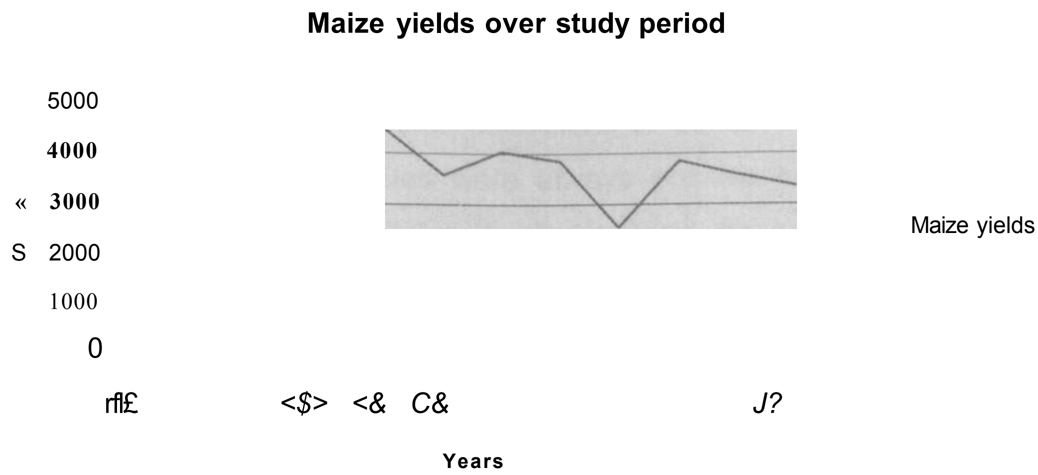
A detailed examination was made of the results obtained followed by a discussion of their significance.

The study made use of the daily temperature and rainfall data from the Trans Nzoia metrological stations in order to establish the relationship between weather variation and yield changes. Hence the descriptive statistics used in the study were the mean, the standard deviation, the variance, the kurtosis and the skewness. These basic statistics revealed the general behavior of the data on a daily basis.

4.1. Maize yield analysis results

The maize yield reports as obtained from the Rift valley annual agricultural reports showed maize yield changes from year to year during the study period. 1988 and 1989 registered the highest yields per hectare with a total of 4500 Kg/Ha. This was followed by 1986 and 1991 with 4050 Kg/Ha and 1992 and 1994 recording 3870 Kg/Ha. 1985, 1987, 1990 and 1995 all recorded 3600 Kg/Ha and lastly 1996 recorded 3330 Kg/Ha. This clearly indicated the occurrence of yield changes during the study period hence, rejecting the null hypothesis one at 95% significant level.

Figure 5: Maize yield variation over the study period.



4.2. Descriptive Statistics Results

4.2.1. January Results for 1985-1996

TransNzoia metrological stations registered a mean temperature of 18.99°c, this being the fourth highest temperature in the months of study. January proved to be hot with mean temperatures over 18°c for the study period and extremes being registered in 1989, 1990, 1992, 1994 and 1996 which recorded means of over 19°c for the month of January (Table 3). The growing season recorded a mean of 18.79°c* in 1993, being the fourth highest temperatures in the years of study (Fig 21).

January was a dry month for the study region and there was no exception when it came to rainfall. Registering a mean of 1.735mm, this was the second lowest in all the months of study. 1989, 1990, 1992, 1994 and 1995 registered a mean of less than 1mm per day with 1994 registering a mean of 0.02, an indication that the years were the worst in terms of dry spell occurrence. However, an exception was 1988 which registered-a January mean of 8.5mm, which was abnormally high for this month. The growing Reason second lowest daily mean was recorded in 1990 at 3.42mm*.

Mean derieved from the growing season temperature and rainfall.

The standard deviation and the variance values were always greater than the means and this showed greater coefficient of variation in daily rainfall. The kurtosis and skew ness values were always positive indicating that extreme cases were those of high rainfall distribution and the normal was low rainfall distribution. Also, even if the kurtosis and skewness values were positive, they tended to be near or less than one thus showing platykurtic tendencies in rainfall distribution (Nyandega 1985)

Generally, January was as a rule a dry month during the period of study and one could conclude from the central tendency statistics that it was the normal feature in the study region. Extreme variations were possibly due to occasional occurrence of heavy downpours but the distribution seemed to be platykurtic, ultimately indicating generally low rainfall conforming with Nyandega's, 1985 study of west Kenya.

4.2.2. February Results for the 1985-1996 Period.

February temperatures were even hotter than Januarys, registering a mean of 19.48°c. This was the third hottest month of the study period. All mean temperatures were above 19.5°c apart from 1986, 89, 93, 95 and 1996 which were however above 18.5°c. 1993 with a mean temperature of 18.84°c* for the growing season, was the third hottest year of the study period.

Likewise, February's mean daily rainfall was slightly higher than Januarys at 2.01mm. There was an improvement in the number of years that recorded a daily mean rainfall of over 1mm with exceptions being 1990 and 1991. The third lowest daily mean rainfall for the growing season was in 1996 at a mean of 3.66mm*.

The standard deviation and the variance values continued to indicate occurrence of variations in the daily rainfall for the month of February. Likewise, the kurtosis and the skew ness values showed great variation which could be attributed to occasional occurrence of heavy downpours.

February was thus a hot month during the whole period of study, recording the third highest mean temperature and third lowest mean rainfall.

4.2.3. March Results for 1985-1996 Period.

March is an important month for the region as it marks the beginning of the rains to the farmers in the region. However, in terms of mean temperatures, March was no better than the first two months. In fact, at a mean of 19.7°c, March was the second hottest month of the study period. Mean temperatures exceeded 19°c in the study period with the only exception being 1989, which recorded a mean temperature of 18.45°c. The second hottest year of study was 1995, which recorded a mean growing season temperature of 18.92°c*.

The data showed improved rains in March with the mean daily rainfall at 4.66mm. There was no month of March in the years of study that recorded a daily mean of less than 1mm, with 1996 and 1990 recording the lowest daily mean rainfall at 1,4mm and 1.5mm respectively. 1989 and 1991 recorded the highest daily means at 7.3mm and 7.1mm respectively, thus these being the wettest month of March in the study period. The fourth wettest year of study as per the growing season mean daily rainfall was 1989, with a daily mean rainfall of 4.56mm*.

The variance and the standard deviation values were greater than the means in most cases indicating great coefficients of variation in the daily rainfall distributions. The skew ness and the kurtosis values showed the occurrence of heavy downpours occasionally, hgnee erratic distribution of the rains.

March daily rainfall was far much better than January and Februarys as the improved daily mean rainfall gave a tendency towards a general increase in rainfall. This confirmed that the rainy season indeed starts in March though late liris are to be expected as shown by the means of 1986, 88, 90 and 1996 at 4mm, 2mm, 1.5mm, and 2.8mm respectively.

4.2.4. April Results for 1985-1996 Period.

April data results indicate that this was the hottest month in the study region at a mean daily temperature of 19.87°c. Mean daily temperatures exceeded 19°c for the period under consideration, the only exception being 1993 which recorded a daily mean of 18.92°c. The highest growing season mean recorded was for 1990 at 18.98°c*.

4.2.5. May Results for 1985-1996 Period

TransNzoia metrological stations reported a mean temperature of 18.89°c for May, this being the fifth highest for the months of study. There were slight variations in the daily means for the study period with temperatures fluctuating between 18°c and19°c, the only exception being 1992 with a daily mean temperature of 17.66°c. 1986 recorded a daily growing mean temperature of 18.76°c, this being the fifth highest in the study period.

Rainfall was exceptional in May, this being the second wettest month in mean daily rainfall in the study period. Registering a mean rainfall of 6.35mm, the data showed a daily mean of over 4mm with the only exception being1990 with a daily mean of 2mm for the month of May. The highest rainfall was recorded in 1993 with a daily mean of 9.9mm followed by1994 with a daily mean of 8.4mm. 1994 recorded the second highest daily rainfall mean for the growing season at 4.79mm*.

*

The coefficients of variation on a daily basis tended to have been considerable with the standard deviation and variance values being generally greater than the mean values. The kurtosis and skew ness values were generally positive showing tendencies towards peaked rainfall distribution and the extreme values most likely to be in the form of heavy downpours.

May rainfall complied with the expected peak in rains which onsets in March in a unimodal form.

4.2.6. June Results for 1985-1996 Period.

June showed a decrease in daily mean temperatures which was ideal as the crops were past the germinating stage. The mean temperature for June was 18.21°c with daily means ranging between 17°c and 18°c with the only exception being 1986 at a daily mean of 19.5°c. June had the fourth lowest daily mean temperatures for the study period. 1996 recorded a daily mean temperature of 18.66°c*, for the growing season.

After the rainfall peaks in April and May, June registered a slight decrease in daily mean rainfall occupying position six in order of total rainfall amounts received. The month recorded a mean of 4.27mm with daily means for the study period ranging from 3mm to 5mm. However, 1991 registered the lowest daily mean rainfall for June at 1.5mm. 1985 recorded a daily mean rainfall of 4.27mm* for the growing season, ranking sixth in the period of study.

The variance and the standard deviation were generally greater than the means showing variation on daily rainfall. The kurtosis and skew ness values were positive but registered low rainfall distribution due to occurrence of heavy downpours.

Though June rainfalls showed a slight decline in rainfall, the amounts received were still sufficient for crop growth and conformed to the unimodal type of rainfall received in the study zone.

4.2.7. July Results for 1985-1996 Period.

July recorded some relatively low temperatures, in fact the second lowest for the study period. The daily mean temperature was 17.94°c with most daily means for this month ranging between 17°c and 18°c, the only exception at 19.4°c being the daily mean temperature of 1992. 1988 recorded the second lowest growing season daily mean temperature at 18.62°c\

July proved to be a wetter month than June with a daily mean rainfall of 5.12mm against Junes 4.27mm making it the fourth wettest month of study. The daily mean rainfall for the month showed mean rainfall well beyond 3mm, exceptional cases recording 7.2mm and 6.6mm in 1985 and 1996 respectively. 1989, with a daily mean rainfall of 4.56mm for the growing season was ranked fourth in the years of study.

Daily coefficients of variation was high with as the values of standard deviation and the variation indicated. Extreme values occurred in 1990 indicating heavy downpours for that season. This trend was also evident in the positive kurtosis and skew ness values.

July rainfall continued to show the unimodal type of rainfall characterized by one long rainy season as experienced by Kenya's highland regions.

4.2.8. August Results for 1985-1996 Period.

August experienced the lowest temperatures in the whole study period. Recording a daily mean temperature of between 17°c and 18°c, August recorded an overall daily mean temperature of 17.9°c in the study period. 1989 had the lowest daily mean temperatures for the growing season at a mean of 18.47°c*.

August was received much rainfall than July bringing up the possibility of a bimodal type of rainfall in the study zone. Being the third wettest month in the study period, August recorded a daily mean rainfall of 5.48mm against July's 5.12mm. The daily mean rainfall for the years were well beyond 3mm with extreme rainfall in 1993 at a daily mean of 11.7mm and 1985 at 8.2mm. In terms of growing season mean, 1987 was ranked third at a daily mean of 4.76mm.

Standard deviation and variance values were greater than the means in most cases, showing existing coefficient of variation in daily rainfall. Extreme cases appeared in 1993 indicating occurrence of abnormally heavy downpours. The skew ness and kurtosis values seemed to confirm this phenomenon in the data.

4.2.9. September Results for 1985-1996 Period.

September recorded a slight increase in temperatures as compared to the coldest month of study that is August. Experiencing a daily mean temperature of 18.2°c, the daily mean for the years of study ranged from 17° to 19°c. This was ideal as the crops reached physiological maturity and need high temperatures for moisture loss before harvesting. The third coldest year of study in terms of daily growing season mean was 1987 at a mean of 18.64°c*.

Rainfall results for September were as expected, in most cases. Recording a daily mean of 3.16mm, September was the fourth driest month of the study period. It was common to get daily means of less than 2mm with the exceptional cases recorded in 1989 and 1986 at daily means of 5.1 and 4.1 respectively. 1995 at a daily growing season mean of 3.68mm* was ranked fourth driest year of study.

The variance and standard deviation were in most cases higher than the means thus giving indication of variation in the daily rainfall. The kurtosis and skew ness values confirmed existence of occasional heavy downpours associated with the high positive values got.

4.2.10. October Results for 1985-1996 Period.

Marking the maturity period, October temperature data indicated a daily mean temperature of 18.5°c. Such ideal temperatures were good for crop moisture loss before harvesting. The daily mean temperatures over the years ranged between 18°c and 19°c, with the only exceptions being in 1990, 1991 and 1996 at 17°c.

October continued to show reduced rainfall ideal for crops drying in the field. Recording a daily mean rainfall of 3.89mm, October experienced years of abnormally high rainfall which could have affected final yields obtained from the fields. 1990 registered a daily mean of 6.8mm and 1992 recording a mean of 6.1mm. The range seemed to be between 2mm and 5mm. 1991 recorded a daily growing mean of 3.77mm making it the seventh driest year of study.

Variance and the standard deviation were in most cases higher than the means hence indicating variation on a daily basis. Kurtosis and the skew ness values were positive and generally above zero showing general tendency to heavy downpours especially in 1990 and 1992.

October rainfalls and temperatures data were good in most cases during the study period to enable crop moisture loss before harvesting. Exceptions however, arose from time to time often with negative effects on the yields.

4.2.11. November Results for 1985-1996.

Considered out of the growing season, November continued to record temperature rise necessary for crops moisture loss. Mean daily temperatures increased to 18.53°c with daily means ranging from 17°c to 19°c.

Rainfall also continued to reduce as the year ended with November recording a daily mean rainfall of 3.84mm. It wasn't uncommon to experience daily mean rainfall of less than 2mm with exceptions occurring in 1987 at a daily mean rainfall of 7.9mm.

Variations continued to occur on a daily basis as was shown by the high values of standard deviation and variance. The kurtosis and the skew ness values were generally above zero showing general tendencies towards heavy downpours.

Hence, November rainfall and temperature were ideal for the study region, in most cases and enabled the moisture loss in the fields as harvesting continued. Exceptions though arose, often with negative effects on the yields as will be seen.

4.2.12. December Results for 1985-1996 Period.

Temperature results for December showed a drastic increase in temperatures registering the highest mean since June at a daily mean of 18.6°c. This was still favorable for harvesting the drying crops from the field. The only exception occurred in 1985 which experienced the lowest daily mean temperature for the entire study period at 16.32°c.

Likewise, December recorded the lowest daily mean rainfall for the entire study period at 1.58mm. The norm was a daily mean rainfall of below 2mm with means of less than 1mm being experienced in 1988, 1991 and 1993. 1994 was an exceptional year recording a daily mean of 3.9mm.

The standard deviation and variance values were in most cases higher than the means thus showing variation on a daily basis. Some large values, especially in 1990 and 1994 showed great coefficient of variation in the daily rainfall for those years. The kurtosis and skew ness values were positive and generally above zero showing general tendency towards heavy downpours at the same time extreme values were mostly to be those of high rainfall distribution.

Table 2: Monthly and Yearly Rainfall means from 1985 to 1996

MONTHLY AND YAERLY RAINFALL MEAN

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL
1985	1.5	1.1	5.9	5	6	4.5	7.2
1986	1.1	2.7 .	1.4	6.8	4.7	1.5	5.2
1987	2.3	.1.7	68	8.7	7.9	3.2	5.8
1988	8.5';*	1.3	2	2.6	5.5	3.5	3.9
1989	0.9	1.7	7.3 I	9	6.6	4.2	4.7
1990	0.3	0.7	1.5	5.4	2	3.3	5
1991	2.2	0.9	7.1	1.8	7.4	3	5.3
1992	0.1	2.2	6.1	10.4	8.1	5.7	4.7
1993	1.3	3.2	4.8	16.3	9.9	5.5	3.2
1994	0.02	2.4	6.6	10	8.4	5.5	4.1
1995	0.8	3.1	3.5	4.5	4.6	5.6	5.7
1996	1.8	3.1	2.8	5.8	5.1	5.7	6.6
MEAN	1.735	2.01	4.66	7.19	6.35	4.27	5.12

AUG	SEPT	OCT	NOV	DEC	MEAN
8.2	2.8	2.5	4	1.7	4.27
4.3	4.1	5.2	2.7	1.5	3.71
3.4	2.3	5.2	7.9	1.7	4.76
4	2.7	2.7	1.6	0.3	2.57
5.6	5.1	3.1	4.6	1.2	4.56
6.4	1.9	6.8	5.7	2.1	3.42
5.9	1.9	3.8	5.4	0.3	3.77
3.1	2.4	6.1	1.7	2.1	4.46
11.7	4.1	2.6	2	0.8	5.44
4.4	4.3	2.1	5.7	3.9	4.79
5.3	2.7	4.2	2.4	1.8	3.68
3.4	3.6	2.4	2.4	1.5	3.66
5.48	3.16	3.89	3.84	1.58	

Table 3: Monthly and Yearly Temperature Means from 1985 to 1996

MONTHLY AND YEARLY TEMPERATURE MEAN

YEAR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT
1985	18.38	20.27	20.87	20.1	19.39	18.43	17.89	17.66	17.73
1986	18.14	18.48	20.1	20.3	18.38	19.5	17.62	18.63	17.08
1987	18.34	19.84	19.62	19.1	18.72	18.23	18.18	17.18	18.65
1988	18.64	19.88	19.22	19.69	19.13	17.43	17.07	18.72	17.49
1989	19.76	18.84	18.45	19.26	19.02	17.9	17.9	17.38	17.4
1990	19.75	21.46	20.25	19.87	18.55	17.59	18.07	18.27	19.2
1991	18.44	19.34	19.05	21.48	19.78	17	18.27	17.49	17.18
1992	20.26	19.93	18.98	19.35	17.66	17.65	19.4	18.34	19.25
1993	18.79	18.91	21.27	18.92	18.45	18.73	17.83	17.05	18.67
1994	19.36	19.5	19.21	20.55	18.64	18.97	17.08	18.64	18
1995	18.34	18.79	20.06	20.4	19.83	18.15	18.11	17.12	19.41
1996	19.66	18.56	19.4	19.37	19.09	18.91	17.89	18.34	18.28
MEAN	18.99	19.48	19.7	19.87	18.89	18.21	17.94	17.9	18.2

OCT	NOV	DEC	MEAN
18.14	19.56	16.32	18.7
19.34	17.73	18.2	18.76
18.34	19.42	18.22	18.64
18.55	18.44	19.26	18.62
19.02	17.93	18.79	18.47
17.75	18.01	19.21	18.98
17.88	18.91	19.42	18.68
19.02	18.37	18.02	18.84
18.69	18.7	19.47	18.79
18.49	17.85	19.03	18.76
18.86	19.07	18.94	18.92
17.86	18.37	18.29	18.66
18.5	18.53	18.6	

Table 4: Variance and Standard Deviation

YEAR	VARIANCE/STANDARD DEVIATION	JAN	FEB	MARCH	APRIL
1985	VARIANCE	2.03	2.03	1.06	6.55
	STD DEV	4.5	3.26	14.5	8.09
1986	VARIANCE	0.42	4.43	0.98	14.7
	STD DEAV	2.05	6.66	3.13	12.1
1987	VARIANCE	1.51	2.3	16.2	22.2
	STD DEV	3.89	4.79	12.7	14.9
1988	VARIANCE	1.05	0.86	1.74	2.84
	STD DEV	3.24	2.94	4.18	5.33
1989	VARIANCE	0.72	1.61	14.5	24.1
	STD DEV	2.68	4.01	12.1	15.5
1990	VARIANCE W	0.17	1.08	1	15.4
	STD DEV	1.32	3	3.16	12.4
1991	VARIANCE	5.36	0.66	25.3	1.73
	STD DEV	7.32	2.58	15.9	4.16
1992	VARIANCE	0	2.56	22.8	46.2
	STD DEV	0	5.06	15.1	21.5
1993	VARIANCE	0.71	2.37	10	93.9
	STD DEV	2.68	4.87	10	30.6
1994	VARIANCE	0	3.71	14.2	50.9
	STD DEV	0.15	6.09	11.9	22.5
1995	VARIANCE	0.43	6.67	5.11	3.91
	STD DEV	2.09	8.17	7.15	6.25
1996	VARIANCE	2.97	2.63	3.09	5.53
	STD DEV	5.45	5.13	5.56	7.43

MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DL
9.34	7.93	11	14.9	2.25	1.33	10.6	0.74
8.24	8.9	9.9	12.2	4.74	3.65	10.3	2.73
5.09	1.48	9.74	6.43	9.14	10.9	2.07	2.22
7.14	3.85	9.87	8.01	9.56	10.4	4.56	4.58
28.4	1.86	8.94	1.45	2.28	12	14.4	1.36
16.8	4.32	9.45	3.81	4.77	10.9	12	3.69
12.95	2.82	3.57	3.49	2.08	3.53	1.6	0.2
11.5	5.3	5.98	5.9	4.56	5.94	4	1.43
90.1	6.79	4.21	5.73	10	2.92	6.12	0.84
94.9	8.24	6.49	7.57	10	5.4	7.84	2.9
1.19	11.1	53.3	16.5	1.14	12.6	9.17	3.68
3.45	33.3	73.1	12.8	3.37	11.2	9.57	6.07
16.1	2.05	5.72	8.27	0.74	6.63	11.9	0.15
12.6	4.53	7.56	9.09	2.72	8.14	10.9	1.25
12.4	7.6	7.96	1.76	2.95	23.8	0.79	1.44
11.1	8.72	8.92	4.19	5.43	15.4	2.81	3.79
16.8	20.7	20.7	47.7	7.72	1.95	2.74	0.44
13.2	14.4	14.4	21.8	8.79	4.41	5.24	2.1
20.5	16.1	16.1	3.66	3.06	1.23	10.9	6.01
14.3	12.6	12.6	6.05	5.53	3.52	10.4	7.75
5.85	10	10	5.79	5.36	5.09	1.07	1.68
7.65	10	10	7.61	7.32	7.13	3.27	4.11
13.2	8.14	8.14	2.79	6.65	1.94	1.04	3.39
11.5	9.02	9.02	5.28	8.15	4.4	3.22	5.83

Table 5: Kurtosis and Skewness Values

YEAR	KURTOSIS/SKEWNESS	JAN	FEB	MARCI-
1985	KURTOSIS	18.2	8.73	10.08
	SKEWNESS	4.08	3.1	3.18
1986	KURTOSIS	2.99	10.21	20.63
	' SKEWNESS	2.02	3.13	4.22
1987	KURTOSIS	3.75	12.39	6.71
	SKEWNESS	2.02	3.48	2.59
1988	KURTOSIS .	27.6	5.1	8.64
	SKEWNESS	5.15	2.38	2.9
1989	KURTOSIS	10.8	10.15	4.79
	SKEWNESS	3.37	3.18	2.32
1990	KURTOSIS	30.3	27.91	8.71
	SKEWNESS	5.48	5.28	2.88
1991	KURTOSIS	25.1	18.6	7.14
	SKEWNESS	4.86	4.27	2.71
1992	KURTOSIS	12.7	5.83	16.02
	SKEWNESS	3.73	2.61	3.88
1993	KURTOSIS	7.37	2.57	11.13
	SKEWNESS	2.56	1.68	3.19
1994	KURTOSIS	31	6.12	10.03
	SKEWNESS	5.57	2.67	2.99
1995	KURTOSIS	7.41	17.53	5.36
	SKEWNESS	2.85	3.98	2.47
1996	KURTOSIS	20.4	6.53	7.47
	SKEWNESS	4.34	2.42	2.82

APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
11.63	1.96	3.94	3.12	4.03	5.29	0.94	11.5	3.11
3.08	1.66	2.2	1.77	2.07	2.47	1.49	3.31	1.84
7.96	3.69	15.3	9.06	11.52	15.8	6.71	4.53	11.8
2.72	2.01	3.81	2.82	3.13	3.73	2.57	2.16	3.42
6.3	19.78	8.85	2.64	0.26	7.78	13.08	2.26	3.93
2.69	4.15	2.67	1.8	1.1	2.86	3.37	1.83	2.2
8.34	13.06	1.96	2.62	1.29	3.68	20.78	8.15	30.29
2.77	3.35	1.76	1.97	1.57	2.14	4.31	2.98	5.46
11.59	2.46	5.26	0.97	1.95	18.1	2.77	4.15	7.52
3.14	1.8	2.35	1.4	1.58	3.96	1.94	2.1	2.83
15.62	6.93	1.97	3.67	16.43	6.66	4.04	2.59	15.81
3.73	2.51	1.41	2	3.77	2.52	2.17	1.9	3.83
5.74	6.05	4.63	5.92	11.46	5.47	10.6	5.89	15.24
2.53	2.44	2.11	2.39	3.07	2.32	3.25	2.6	3.95
6.21	7.47	10.6	6	4.8	8.37	10	1.31	6.18
2.53	2.68	2.91	2.5	2.02	2.93	3.23	1.65	2.36
12.34	13.09	15.1	2.49	13.85	19.8	6.07	12.99	8.96
3.35	3.17	3.7	1.64	3.41	4.18	2.57	3.54	3.04
15.91	7.54	20	7.86	2.64	2.35	3.47	7.09	5.59
3.81	2.64	4.24	2.64	1.75	1.82	2.04	2.56	2.49
3.19	8.45	3.99	2.09	4.5	14.1	6.51	0.65	8.34
1.86	2.68	2.2	1.75	2.16	3.73	2.5	1.31	2.9
6.27	22.4	2.91	3.63	4.8	18.9	8.7	-0.01	23.94
2.44	4.52	1.89	1.99	2.11	4.11	2.79	1.16	4.78

4.3. Time Series Analysis

4.3.1 Results for March 1985-1996 Time Series.

TransNzoia March rainfall Time Series analysis showed the onset of rainfall in most years of study period. Rainfall was generally below 5mm with the exception of a few years recording rainfall of above 5mm. March registered high peaks in several years thus showing poor distribution as confirmed by the descriptive statistical results. The onset of March rainfall were all within the first two days of the month but varied widely in intensity.

The first six years of study (1985-1990), showed rainfall of below 5mm in most years with the exception being 1987 and 1989. These two years recorded several peak rainfall, indicating the occurrence of heavy downpours. Onset of rains delayed in several years namely 1986 and 1990 though the series showed an improved rainfall in the last days of the month for 1990. The delayed onset of March rainfall was expected to affect yields in these years. 1988 Series indicated good rainfall distribution, a fact that was confirmed by the descriptive statistics results. This greatly improved yields as the seeds were just germinating.

The second six years of study (1991-1996), was no different from the first six years with the onset of rains in the first two days of the month. The only exception was 1991 which had a seven day break before the onset of rains. The rains were generally better than the first six years of study but the less than 5mm rainfall dominated the Series. There was poor rainfall distribution in most years with high peaks indicating heavy downpours and gap showing erratic rainfall in the Series in 1991, 1992, 1993, and 1995. However 1994 had rainfall of > 5mm dominating the Series. 1996 Series showed low rainfall which neither the less were well distributed as confirmed by the descriptive statistic results.

Time Series analysis for March rainfall showed that March rains followed more or less the same trend. The variations occurred in the date of rainfall onset, means and rainfall distribution. The breaks however occurred in the Series for all years of study but were never complete. Though variation occurred in the Series from year to year, it was difficult to outline a trend to this variation.

Figure 6: **March Time Series 1986-1990**

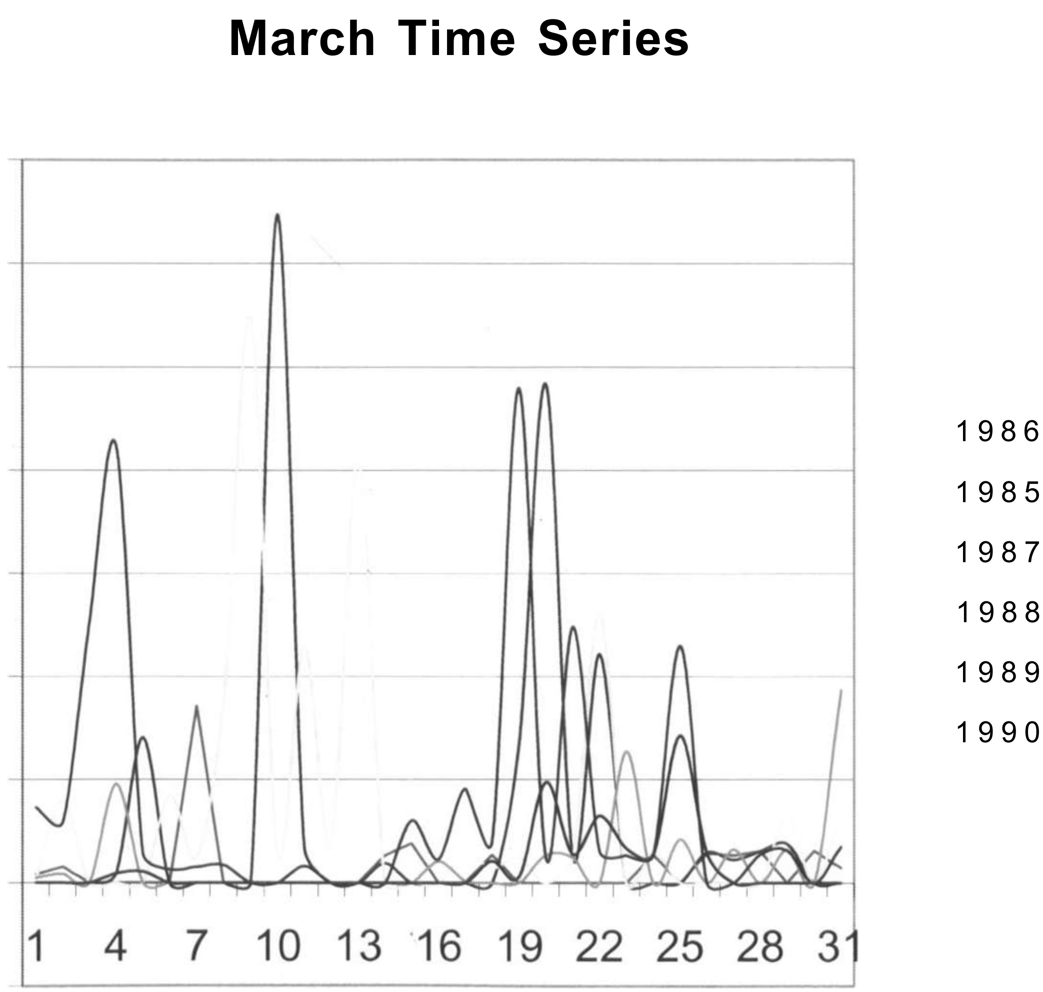
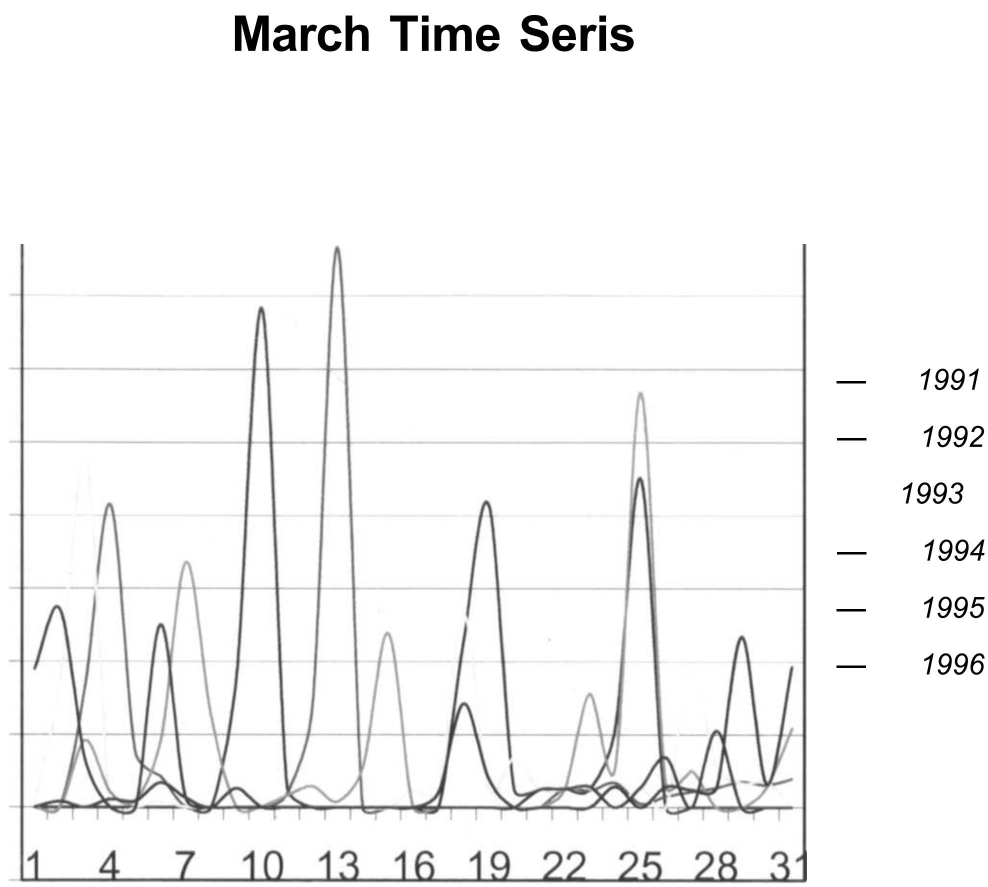


Figure 7: March Time Series 1991-1996



4.3.2. April Results for 1985-1996 Time Series.

Time Series analysis for TransNzoia April rainfall portrayed April rains as the highest in the study zone. Rainfall over 5mm was dominant in the series. The gaps, when present, were not complete indicating erratic rainfall in April throughout the series. Generally, april rainfall was good in the study zone.

The first six years of study (1985-1990), had onset of rains within the first four days of the month. The rains were relatively high from the day of onset with rains of over 5mm dominating the Series in 1985, 86, 87, 89 and 1990. There were gaps in the Series showing erratic rains, as the breaks were never complete. The high number of peaks indicated occurrence of heavy downpours during April. 1988, however, registered the lowest rainfall, which peaked at the end of the month.

The second six years of study (1991-1996), also registered exceptionally good rainfall with rains of over 5mm dominating the Series. The onset of the rains was in the first four days of the Series with high peaks in the first and last ten days being recorded. 1993 showed exceptionally poor rainfall distribution due to occurrence of frequent heavy downpours. 1992, 93 and 1994 showed exceptionally high rainfall, which could have led to water logging in the fields leading to poor germination of maize seedlings.

4.3.3. May Results for 1985-1996 Time Series.

The TransNzoia May rainfall time series continued to show heavy rainfall throughout the years of study with a few exceptions here and there. Rainfall was generally above 5mm with the onset of rains falling within the first two days of the month. There were no complete breaks in the series with gaps of between a day and three days experienced between wet days.

Series results of the first six years of study (1985-1990) showed presence of heavy downpours, majority being above 10mm. The peaks were random in the month over the period of study with 1989 showing the highest number of rainfall peaks above 10mm followed by 1987. There occurred intermediate breaks within the Series indicating erratic rainfall. The onset of the rains occurred within the first two days but May experienced a poor rainfall distribution as confirmed by the basic statistics results earlier. 1990 recorded a well distributed rainfall though the amounts were abnormally low for the month of May. Variation tended to exist within the series for the six years of study.

The second six years of study (1991-1996) recorded higher rainfall for the May Series. Rainfall was generally above 5mm with 10mm peaks being common in the series. Heavy downpours dominated the series in the years of study with the highest peaks being recorded within the last ten days of the series. Intermediate breaks continued to occur within the series but were less as compared to the first six years of study.

Poor rainfall distribution continued to be the norm mainly due to the heavy downpours experienced in the Series. Variations still tended to occur from one year to the other in term of daily rainfall recorded, mean, gaps in the Series and rainfall distribution.

4.3.4. June Results for 1985-1996 Time Series.

As compared to the previous month, June rainfall was slightly low in most of the study period. The onset of June rainfall was a continuation of the May rainfall hence, it was in the first day of the month in the first six years of study. 1985, 1988 and 1990 rain onset was at peak levels. There were random peaks at the beginning of the month in 1986 and 1987 too. 1985 experienced a complete break in precipitation for a record thirteen days in the Series. However, gaps in other years of study were not complete with breaks of up to three days occurring. Rainfall in the first six years of study was generally below 5mm with occasional heavy downpour of up to 35mm. 1986 recorded abnormally low rains in the Series as compared to other years of study.

The second six years of study (1991-1996) were no different from the first though rainfall generally improved to above 5mm. The onset of June rainfall was still within the first day apart from 1996 that recorded a four day break before the onset of the rains. Peak rainfall continued to be recorded within the first ten days of the month, showing a continuation from the previous months rainfall. Like the first six years of study, there were no complete breaks within the cycle showing continuous but erratic rainfall. 1991 recorded the lowest rainfall in the Series but the rains were well distributed as confirmed by the basic statistic results.

The second six years of study therefore showed June to have recorded better rainfall than the first six years of study. Rainfall of above 5mm though present in the first six years of study, was the norm in the second six years of study. Peak rainfall exceeded 70mm in the second six years of study. The highest peaks occurred between the 5th day and the 13th days of the month. Variation was high throughout the study period but exceptional in the second six years of study.

Figure 8: June Time Series 1985-1990

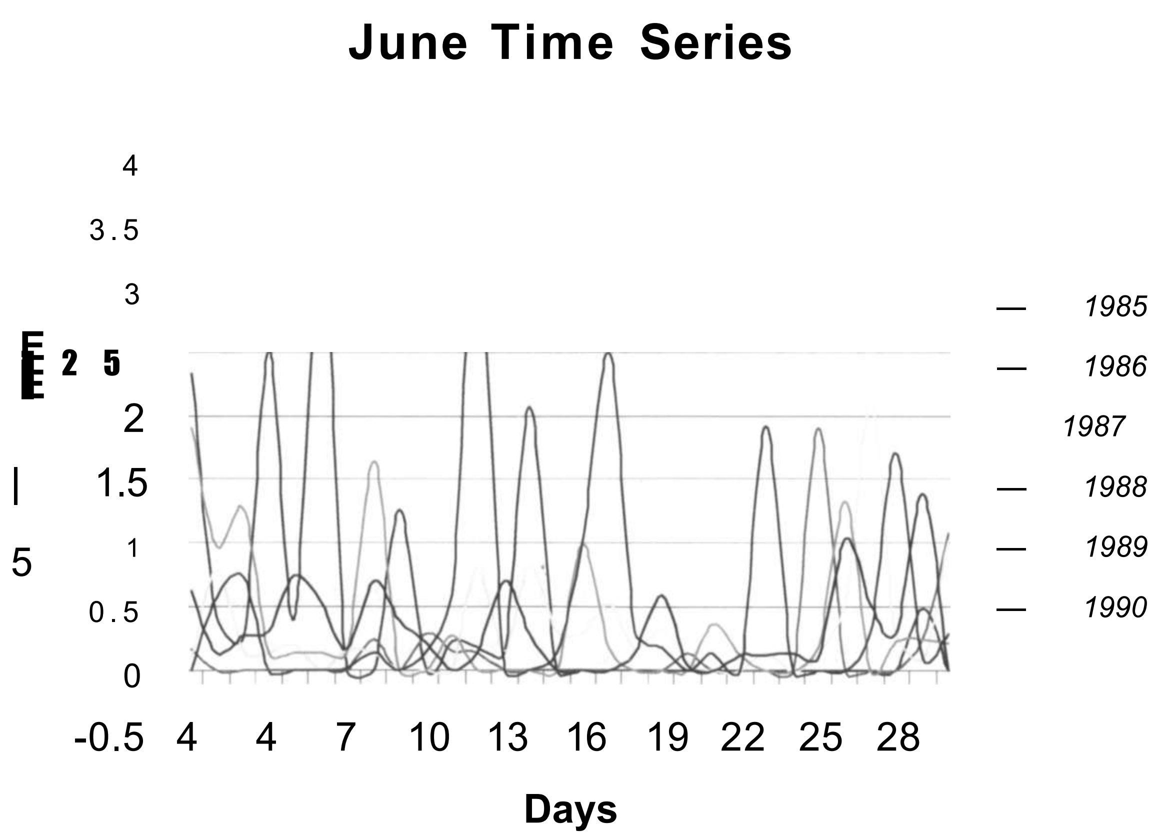
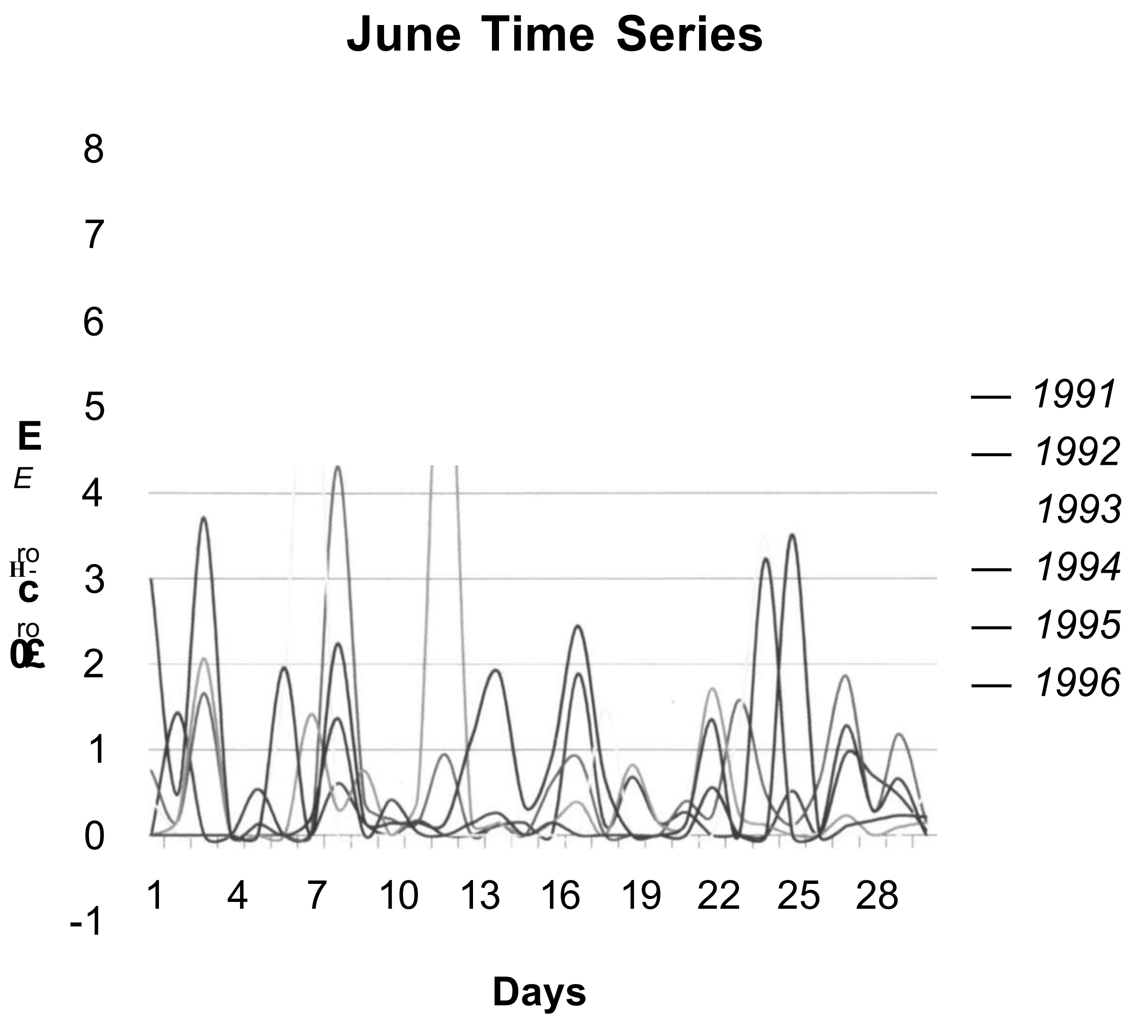


Figure 9: **June Time series 1991-1996**



4.3.5. July Results for 1985-1996 Time Series.

The TransNzoia area July rainfall Time Series showed high rainfall poorly distributed as confirmed by the basic statistics results earlier. The kurtosis and skew ness values confirmed low rainfall distribution due to heavy downpours as shown by the Series. Variation on a daily basis tended to have been great for July rainfall. This was displayed by the large number of peaks in the July Series and confirmed -by the large values of standard deviation and variance than the mean.

The first six years of study (1985-1990) Series analysis indicated frequent breaks in the rainfall. These gaps however weren't complete but it wasn't uncommon to find a five day gap especially in 1986 and 1987. 1988 showed a break of only two days in the Series with well distributed rainfall. 1985 had the highest number of peaks and a three day gap. This lead to poor rainfall distribution in the year. Rainfall on a daily basis tended to be above 5mm with peaks of over 10mm in the Series.

The second six years of study (1990-1996) showed little difference from the first six years. Peak rains of over 10mm tended to dominate the Series with over 5mm rains the norm. The second six years of study had less gaps in the series the largest being three days. 1995 and 1996 recorded a high number of peak rains. Poor rainfall distribution as confirmed by the basic statistics results. 1993 recorded an abnormally low rainfall, factors that could have reduced yields in the year of study.

The common characteristic of the July Time Series was the random high peak rains in all the years of study ranging from 5mm to 45mm. All the years had onset of July rainfall on the first day of the month. Some years such as 1985 and 1996 recorded erratic rainfalls. Variation from year to year however still tended to occur as shown by the series.

4.3.6. August Results for 1985-1996 Time Series.

TransNzoia area rainfall Time Series indicated high rainfall in August indeed this proving to be a peak rainfall month in the years of study. Rainfall in August was generally above 5mm daily with 10mm and above peaks common. The number of rainfall days with over 5mm was more than the number of dry days in the month of August in all the years of study.

The first six years of study had rains from the beginning of the month in the first two days. Gaps in the series were not complete indicating erratic rains. There were small breaks in 1986, 1988, and 1989 though the crops were now at a very mature stage. These years recorded very good yields per hector compared to other years in the study. August rainfall for the first six years of study was generally above 5mm daily though 1987 tended to have experienced less rainfall in August as compared to other years of study. 1988 had a well distributed rainfall showing less peaks in the Time Series.

Early rains were the trend in the next six years of study (1991-1996), with the onset of rains being on the first day of August for all the years of study. The rains were generally above 5mm with the number of peak rainfall days exceeding number of breaks/gaps. Heavy rainfall thus was the norm rather than dry days. 1992 showed less rainfall in the Series as compared to other years of study but the rains were well distributed as confirmed by the basic statistic results early.

Variation tended to occur from year to year in rainfall for the month of August. Rainfall peaked throughout the month with no major gaps identified in the Series. However, rainfall distribution and amounts differed from year to year in the month of August for the period of study.

4.3.7. September Results for 1985-1996 Time Series.

The September rainfall Time Series portrayed the September rains as relatively low within the study region. The first six years of study showed September prone to experience gaps within the cycle, thus indicating the occurrence of dry days within wet days. These intermediate gaps indicated a well distributed rainfall especially in 1988 where a dry day was most likely to be followed by a wet day. The year recorded impressive yields per hector. 1987 also showed gaps within the cycle but these gaps were a little too many resulting in a dry month with occasional peak rainfall hence posting a poor rainfall distribution for the month.

Most rains continued from August resulting in little breaks from the previous month.

The same scenario was repeated in the next six years of study (1991-1996) with peak rainfalls starting at the beginning of the month as a continuation from the previous month. The only exception was 1996 which recorded a seven day break between the two months. 1993 and 1994 recorded maximum breaks of three days each compared to 1992 and 1995 fifteen days break. Peak rainfall occurred within the first twelve days in the first six years of study. This was as a result of continued peak rainfall from the previous month. However, the second six years of study had a widely distributed number of peak rains, the most frequent being 1994. This coupled with only three days gap within the Series might have contributed to the poor yields achieved in that year.

September thus had frequent occurrence of heavy downpours with dry days being more frequent. Many days however, experienced rainfall of less than 5mm with frequent occurrence of dry days intermingling with wet days.

4.3.8. October Results for 1985-1996 Time Series.

The first few days of October rainfall Time Series showed high rainfall of over 5mm in the first six years of study, that is, 1985-1990. This was accompanied by peak rainfall of over 10mm in most cases. Rainfall continued to be received from the beginning of the month with the latest date of onset being the fourth day of the month.

However, the first six years of study had rainfall of below 5mm generally with occasional peaks mostly in 1993. Rainfall delayed up to the 10^{th} day of the month in 1992 and the seventh day in 1994. The breaks in the cycle were even experienced in 1995, within the first ten days of the cycle.

The breaks within the cycle were more pronounced in the second six years of study (1991-1996) than the first. The first six years of study experienced daily gaps in the Series at intervals indicating occasional occurrence of dry days in between wet days. Total dry days amounted to around six except in 1988 (eight), and 1989 (thirteen) contributing to the highest yield per hectare achieved in these two years.

The second six years of study (1991-1996) had prolonged gaps in the cycle at times extending to ten days as in 1992 and 1993. The last six years of the study posted poor yields compared to the first six years attributed partially to erratic rainfall among other factors.

October rainfall time Series indicated peaks that were abnormally high in some years of study. 1985, 1986 and 1990 showed high peaks indicating occasional occurrence of heavy downpours in the first six years of study. These years of study also registered a high daily mean rainfall with poor distribution as shown by the basic statistics results earlier. Yields achieved in these years were also the lowest, indicating a relationship between weather variation and maize yield.

Though the general trend was more or less the same, variation occurred in the daily rainfall received for the month over the study period, the breaks/ gaps in the series, the rainfall peaks and distribution.

Figure 10: October Time Series 1985-1990

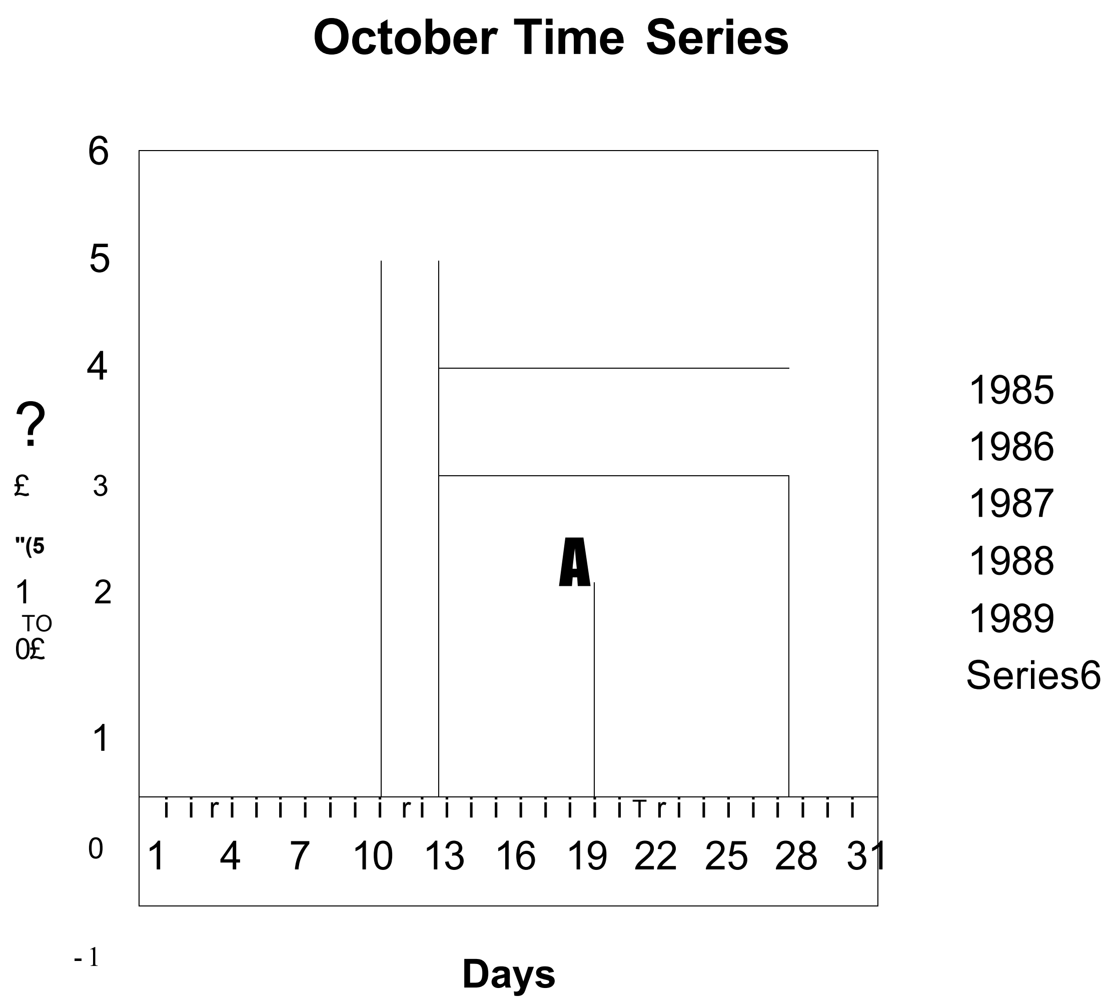
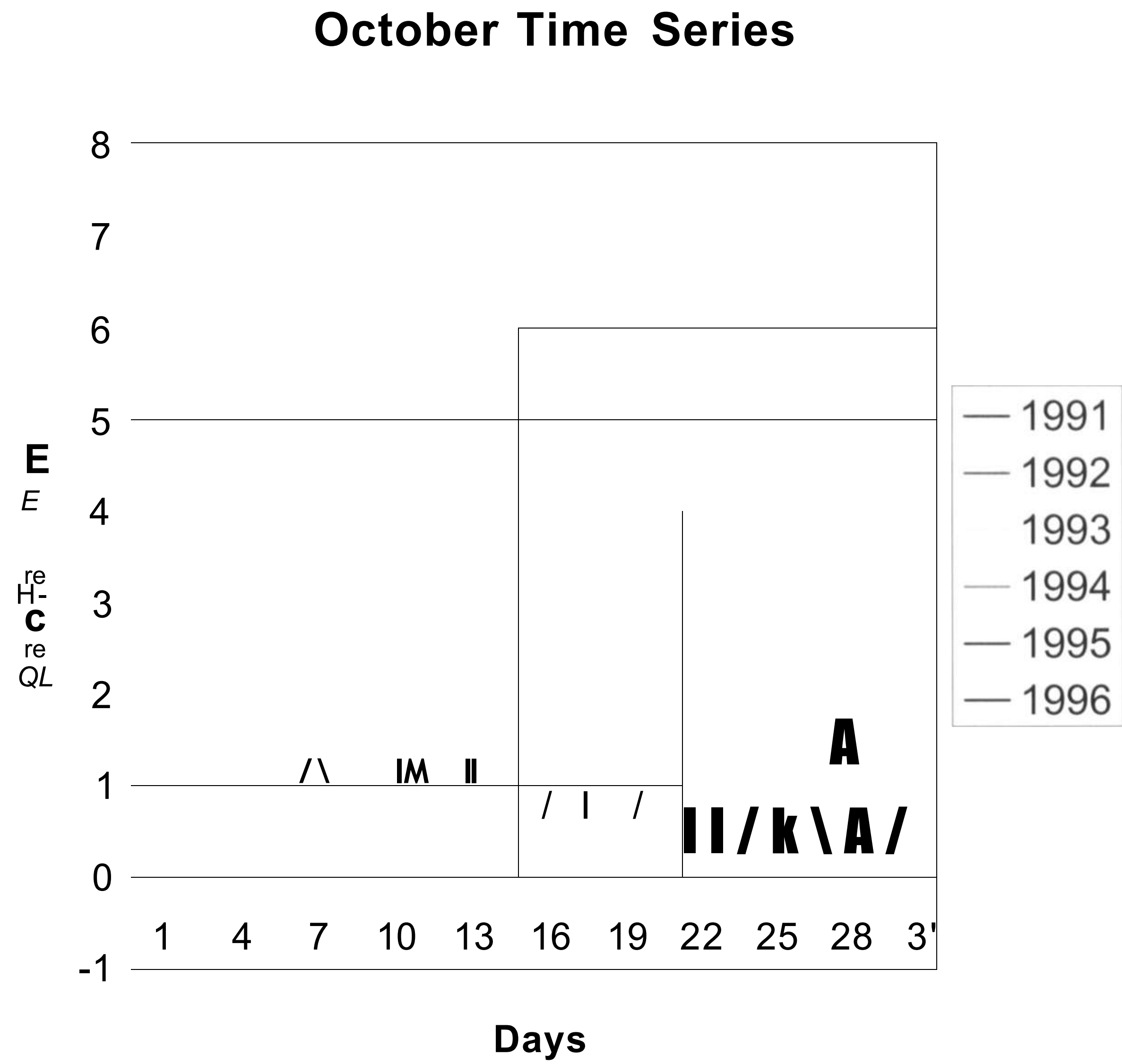


Figure 11: October Time Series 1991-1996



4.4 Regression and Correlation Analysis

4.4.1 Correlation Analysis

When two variables vary together, statisticaians say that there is a lot of covariation or correlation. The correlation coefficient, r, quantifies the direction and magnitute of correlation.

Correlation is not the same as linear regression, but the two are related. Linear regression finds the line that best predicts Y from X. Correlation quantifies how well X and Y vary together. Since both variables are measured, performing correlation analysis makes sense. Correlation calculations does not discriminate between the two variables, but rather quantify the relationship between the two variables.

There is perfect correlation between mean rainfall and mean rainfall; so is there perfect correlation between mean temperature and mean temperature; and yield to yield likewise. There is also perfect negative or inverse correlation between mean temperature to mean rainfall; mean temperature to yield; and finally mean rainfall to yield. This can be explained in the following three ways;

- X variable helps determine the value of Y variable
- Another variable influences both X and Y
- X and Y don't really correlate at all, and the relation happened by chance.

The significant variations we need to understand are as follows;

1) Mean temperature to .mean rainfall.

0.58% of the variance in mean rainfall can be explained by variations in mean temperature. Hence there is no significant collinearity between the independent two variables, that is, rainfall and temperature. At a value of 0.58%, the collinearity and possibility of a linear relationship between the two independent variables is not significant to affect the results with the dependent variable, that is, maize yields.

2) Mean rainfall to yield

26% of the variance in yields goes along with variations in mean rainfall. There is therefore a significant collinearity between mean rainfall and yields that warranty further investigations using regression analysis to establish how yields respond to rainfall.

3) Temperature to yields

19% of the variance in yields can be explained by variation in mean temperature. Though slightly lower than the response yields display with rainfall, this was considered significant enough to warranty further investigations through regression analysis.

From the small P-value attained, the probability of the correlation occurring due to a coincidence was rejected.

Table 9: Correlation Table

VARIABLE	to	*VARIABLE*	*VALUE*
MEAN RAINFALL	to	*MEAN RAINFALL*	*1*
MEAN. TEMP	to	*MEAN RAINFALL*	*-0.075559542*
YIELD/HA(Bags)	to	*MEAN RAINFALL~*	
YIELD/HA(Bags)	*to*	*MEAN RAINFALL*	*-0.5}^* 71791
YIELD/HA(Bags)	to	*MEAN TEMP*	-0.442735521

4.4.2 Regression Analysis

The regression and correlation analysis were run from a computer model. The results generated are shown in the tables 6, 7, 8, and 9.

1) Results for Maize yields and mean rainfall.

The regression analysis was carried out for maize yield and mean rainfall. In this model however, only 19% of the proposition of the variance in maize yield is explained by variations in mean rainfall. The conclusion that this model does not fit the data and thus maize yield variation could not be sufficiently explained by rainfall alone.

2) Maize yield and temperature

The regression analysis of maize yield and temperature is shown by the results in table 7. This model was extremely not suitable at a significance F of 0.149 which is way above the recommended 0.05. Only 11% of the variance in maize yields could be attributed to mean temperature and the error was extremely high. In conclusion, maize yields variation could not be explained by temperature variation.

3) Mean rainfall/ mean temperature and yield

The third regression analysis run on the model had two independent variables namely mean rainfall and mean temperature. Hence at a degree of freedom of two this produced a Significance F at 0.045. This explains that maize yield variation can be attributed to changes in both rainfall and temperature.

Table 8: Results for Maize yield and Mean Temperature and Rainfall Regression Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.514172
R Square	0.264373
Adjusted R Square	0.19081
Standard Error	5.316623
Observations	12

ANOVA

	df	SS	MS	F	Significance F
Regression	1	101.5852	101.5852	3.593839	0.087233
Residual	10	282.6648	28.26648		
Total	11	384.25			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	57.90896	8.660889	6.686261	5.46E-05	38.61129	77.20663
MEAN RAINFALL	-3.95004	2.083638	-1.89574	0.087233	-8.59268	0.692595

Table 8: Results for Maize yield and Mean Temperature and Rainfall Regression Analysis

SUMMARY OUTPUT.

Regression ^Statistics	
Multiple R	0.442736
R Square	0.196015
Adjusted R Square	0.115616
Standard Error	5.558159
Observations	12

ANOVA

	df	SS	*MS*	*F*	*Significance F*
Regression	1	75.31866	75.31866	2.438039	0.149487
Residual	10	308.9313	30.89313		
Total	11	384.25			

	Coefficients	*Standard Error*	*tStat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	394.9653	226.2195	1.745938	0.11141	-109.083	899.014
MEAN TEMP	-18.8532	12.0744	-1.56142	0.149487	-45.7567	8.050208

Table 8: Results for Maize yield and Mean Temperature and Rainfall Regression Analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.705429
R Square	0.49763
Adjusted R Square	0.385992
Standard Error	'4.631245
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	191.2141	95.60707	4.457533	0.045145
Residual	9	193.0359	21.44843		
Total	11	384.25			

	Coefficients	*Standard Error*	*t Stat*	*P-vaiue*	*Lower 95%*	*Upper 95%*
Intercept	445.4756	189.742	2.347796	0.043462	16.24901	874.7023
MEAN RAINFALL	-4.23119	1.820235	-2.32453	0.04515	-8.34886	-0.11353
MEAN TEMP	-20.6254	10.08964	-2.04421	0.071278	-43.4497	2.19898

CHAPTER FIVE

5.0. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS.

5.1. Summary.

Kitale hybrid flowers in about three and a half months at 1,800m. The period to physiological maturity is about six months at 1,500m, seven months at 1,800m, and eight months at 2100m. The young maize plant is moderately drought resistant but is usually susceptible to unfavorable soil air/ moisture relationship during the first 4 or 5 weeks of it life. The optimum rainfall during this 5 weeks after sowing is 200mm. From 5 weeks onwards the maize plant is less drought resistant.

This study was carried out to specifically check the relationship between weather variation and maize yield changes. It therefore became necessary to certain the occurrence of weather variation and maize yield changes hence the application of the methodology outlined earlier. The data needed for the study were the daily rainfall and temperature totals and maize yield data.

The daily temperature and rainfall data were then subjected to descriptive statistical techniques and finally Time Series analysis was carried out. The statistics showed that the daily rainfall were low relatively in December, January, February and September. This was followed by November, October, June and March in that order, being relatively wetter. Maximum rains were received in the months of July, August, May and finally April, with April being the wettest of all the months. The daily mean rainfall for the growing season were worked out from March during the rain onset to October, after physiological maturity of the maize crop.

The mean, variance* standard deviation, skew ness and kurtosis were worked out. The descriptive statistical results showed significant variation in yearly yield, daily rainfall and temperature means distribution, occurrence of heavy downpours and break/ gaps in rainfall.

summary of the relationship among the yearly temperature, rainfall and yields is shown in table 11 and table 13 shows a summary of the relationship among yearly rainfall and temperature means and yield attained. Table 12 and 14 compare the highest to lowest monthly mean temperature and rainfall respectively. The growing season mean rainfall and mean temperature is represented in figure 20. Monthly mean rainfall and temperature summary is shown in figure 21.

It should be noted that rainfall and temperature though explained over 50% variation in yield did not factor in the socio-economic aspects of farming. For example in 1987 most farmers did not prepare land early as National Cereals and Produce Board (NCPB) failed to pay farmers on time. In 1996, there was a very high incidence of stalk borer due to late planting, 1994 and 1995 had very low maize prices reducing farmers moral to planting.

Table 10: Comparison between Rainfall and Temperature Yearly mean and growing season mean and yields attained

YEAR	YIELD/HA(KGS)	YEARLY MEAN		GROWING SEASON MEAN	
		MEAN RAINFALL	MEAN TEMP	MEAN RAINFALL	MEAN TEMP
1985	3600	4.27	18.7	5.26	18.78
1986	4050	3.71	18.76	4.15	18.87
1987	3600	4.76	18.64	5.43	18.5
|I988	4500	2.57	18.62	3.36	18.41
'1989	4500	4.56	18.47	5.7	18.29
1990	3600	3.42	18.98	4.04	18.69
1991	4050	3.77	18.68	4.53	18.52
1992	3870	4.46	18.84	5.83	18.71
1993	2520	5.44	18.79	7.26	18.7
1994	3870	4.79	18.76	5.68	18.7
1995	3600	3.68	18.92	4.51	18.99
1996	3330	3.66	18.66	4.43	18.64

fable 11: Highest to lowest Yearly Mean Temperatures and corresponding Yearly Mean Rainfall and yields attained

	TEMPERATURE	YEAR	RAINFALL	YIELD/HA(KG)
1	18.98	1990	3.42	3600
2	18.92	1995	3.68	3600
3	18.84	1992	4.46	3870
4	18.79	1993	5.44	2520
5	18.76	1994	4.79	3870
6	18.76	1986	3.71	4050
7	18.7	1985	4.27	3600
8	18.68	1991	3.77	4050
9	18.66	1996	3.66	3330
10	18.64	1987	4.76	3600
11	18.62	1988	2.57	4500
12	18.47	1989	4.56	4500

Table 12: Highest to lowest Monthly Mean Temperatures and corresponding Monthly Mean Rainfall

	TEMPERATURE	MONTH	RAINFALL
1	19.87	APRIL	7.19
2	19.7	MARCH	4.66
3	19.48	FEBRUARY	2.01
4	18.99	JANUARY	1.74
5	18.89	MAY	6.35
6	18.6	DECEMBER	1.58
7	18.53	NOVEMBER	3.84
8	18.5	OCTOBER	3.89
9	18.21	JUNE	4.27
10	18.2	SEPTEMBER	3.16
11	17.94	JULY	5.12
12	17.9	AUGUST	5.48

Table 13: Highest to Lowest Yearly Mean Rainfall and corresponding Yearly Mean Temper; yields attained

	RAINFALL	YEAR	TEMPERATURE	YIELD/HA(KGS)
1	5.44	1993	18.79	2520
2	4.79	1994	18.76	3870
3	4.76	1987	18.64	3600
4	4.56	1989	18.47	4500
5	4.46	1992	18.84	3870
6	4.25	1985	18.7	3600
7	3.77	1991	18.68	4050
8	3.71	1986	18.76	4050
9	3.68	1995	18.92	3600
10	3.66	1996	18.66	3330
11	3.42	1990	18.98	3600
12	2.57	1988	18.62	4500

Table 14: Highest to Lowest Monthly Mean Rainfall and corresponding Monthly Mean Temper^

	RAINFALL	MONTH	TEMPERATURE
1	7.19	APRIL	19.87
2	6.35	MAY	18.89
3	5.48	AUGUST	17.9
4	5.12	JULY	17.94
5	4.66	MARCH	19.7
6	4.27	JUNE	18.21
7	3.89	OCTOBER	18.5
8	3.84	NOVEMBER	18.53
9	3.16	SEPTEMBER	18.2
10	2.01	FEBRUARY	19.48
11	1.74	JANUARY	18.99
12	1.58	DECEMBER	18.6

Figure 12: Growing Season Mean Rainfall and Mean Temperature

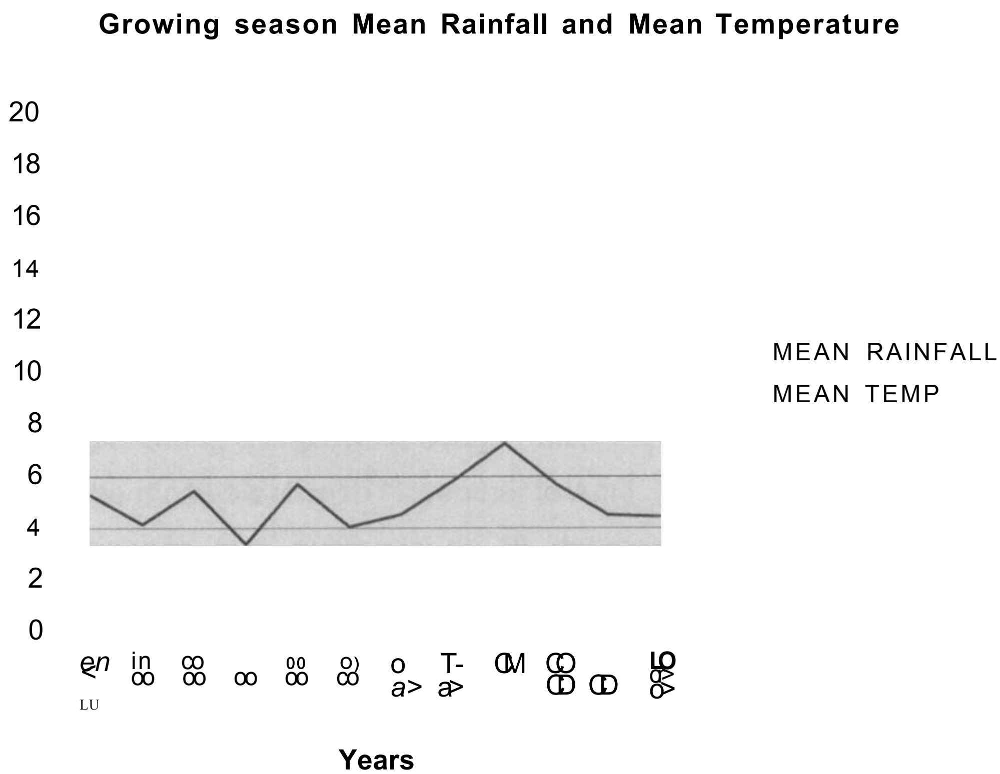
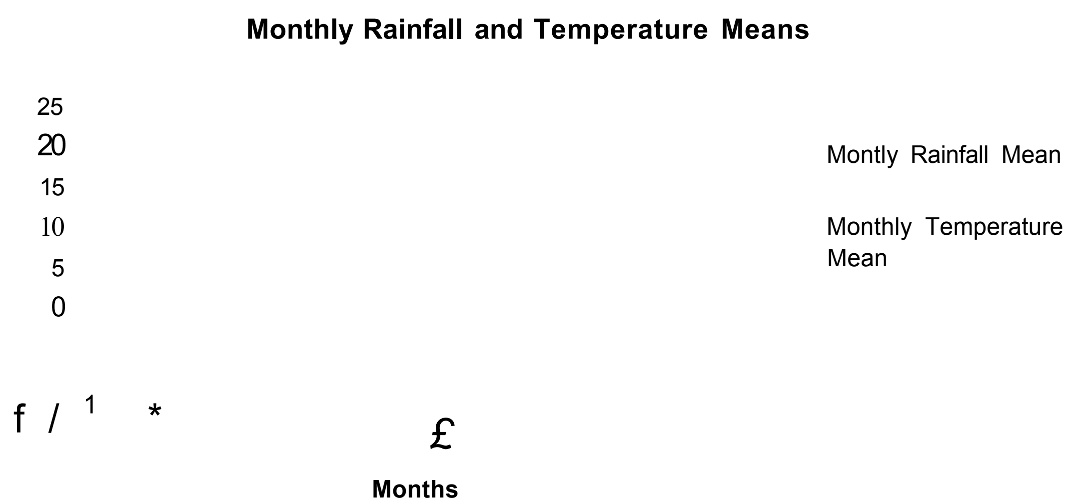


Table 13: Monthly Mean Rainfall and Temperature



5.2 Conclusion

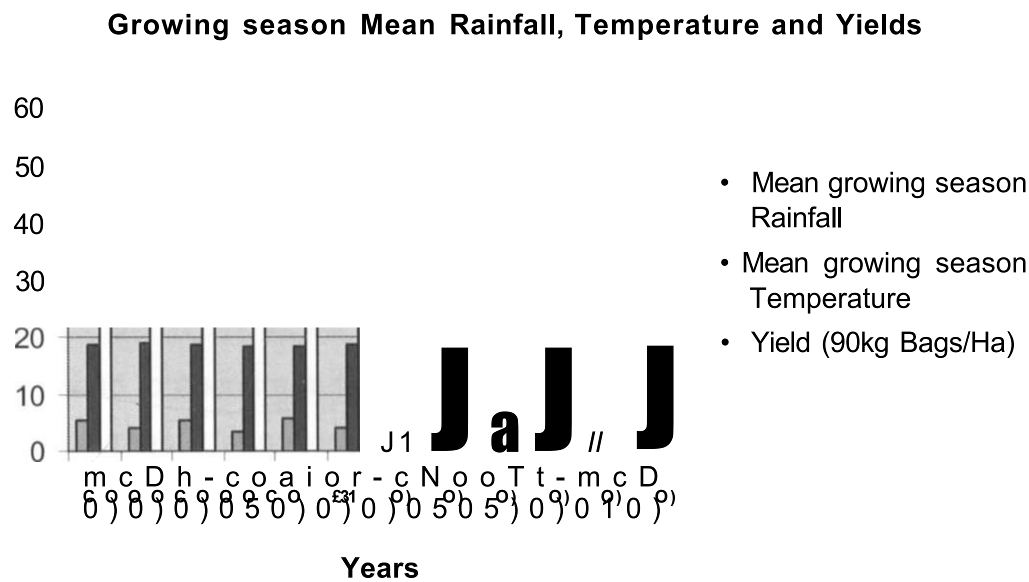
On farm trials often yield 75- 87 bags per ha while farmers yield is often 63- 76 bags per ha. The area plants hybrid maize H614/ H626 and has There is a slight relationship between growing season mean rainfall and mean temperature which was not considered significant enough to affect the maize yield analysis. This is represented in figure 20 and statistically proven in table 9 where the correlation between mean rainfall and mean temperature is -0.075559542. This applies to the relationship between mean rainfall and mean temperature as shown in figure 21. However, mean temperature reduces and almost steadies at 18 degrees Celsius during the growing season then increases to almost 20 degrees Celsius thereafter for the months between November to April. (Figure 21) The mean temperature for the growing season was averages at 18 degrees Celsius. This resulted in a poor relationship being exhibited between the two as shown in figure 24. The regression analysis between maize yield and mean temperature showed a Significance F at 0.149487, thus confirming that maize yield changes could not be explained by temperature variation as the Significance F was more than 0.05%. (table 7)

Rainfall however, showed a slight relationship with maize yield. The Significance F in the regression analysis for maize yields and mean rainfall was 0.087233, slightly above 0.05%. (table 6) This was due to abnormalities especially in 1993 where increased rainfall with a daily growing season mean of 7.26mm led to reduced yields of 2520 kg/ha and 1988 where reduced rainfall with a daily growing season mean of 3.36 resulted in increased yields of 4500 kg/ha.

A combination of mean temperature and mean rainfall can however, explain the variation in yield as shown by results in table 8. A regression analysis of maize yield and mean temperature and mean rainfall had a Significance F of 0.045145. This represents a significant relationship between the dependent variable (maize yields) and independent variables (rainfall and temperature). The statistical analysis show that a combination of the two independent variables that is, mean temperature and mean rainfall will estimate 50% probability of yields at 95% confidence level using this model.

Time series analysis could however, not map a trend in this variation, but just confirm the existence of these variations probably due to the limited number of variables used and the major fluctuations such as El-nino rains in 1993.

Figure 14: Growing season mean Rainfall, Temperature and Yields.



5.3 Recommendation

The study set out to asses maize yield changes in relation to climate variability in view of the consensus of scientific evidence that the 21 st century society will need to learn to mitigate, adopt and cope with accelerated weather variation and possibilities of climate change. East Africa's livelihood system is recognized as agriculturally dependent and is therefore likely to respond to climate variability and frequency of extreme events, including floods and drought. Trans Nzoia district was chosen as the study are after consideration of several factors, mostly due to the area being one of the leading zones in maize production in Kenya, and situated in a highland region. The period of study was arrived at due to occurrence of extreme weather variation such as in 1988 and 1993 and the availability of data during this time period.

There is a need to encourage farmers to collect data on a continuous basis in there fields. This will encourage information flow and research with real time data in the field. Policies should also be designed with an aim to empower farmers in the light of expected climate change so as to avoid the responsive nature of our governments actions.

To asses the impacts of climate variability at the regional level more accurately, there is need to develop regional climate models to project country and provincial level climate change scenarios using locally available data. This model should be able to incorporate most variables namely rainfall, temperature, humidity, land management, fertilizer use, e.t.c

The perspective deduced from the study was that a temperature increment of 1 degree Celsius for East Africa as projected by global climate change model will have little impact on maize yields in the highlands. This is due to the mean growing season temperature leveling at almost 18 degrees Celsius hence an increase of one degree will still be in the maize temperature threshold thus cause little to no impacts on maize yields in these regions. However, an accompanied change irv rainfall will definitely cause a change in maize yields as shown by the results in table 8.

There is need for more research to develop maize seeds that will absorb the expected changes and take into account changes in maturity periods to counter effects of climate change.

APPENDIX

Table 15: Kitale Rainfall totals since 1961 to 1978.

KITALE MET STATION REPORT SINCE 1961 TO 1978

YEAR	RAINFALL MM
1961	1648.2
1962	1442.7
1963	1685.4
1964	1265.9
1965	1144
1966	1237.9
1967	1339.3
1968	1191
1969	1149
1970	1261.3
1971	1358
1972	1231
1973	1132
1974	1298.1
1975	837.6
1976	1024
1977	1397
1978	1404.9

Table 16: Trans Nzoia Rainfall Stations 1994/1996.

STATION 1994	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC
KITALE MET	0.4	13.5(3)	97.4(9)	160.6(19)	175.7(20)	130.3(17)	180.9(18)	208(17)	27.4(15)	183(16)	185.7(17)	29.0(2)
AMS DAO	0	10.5(5)	60.9(9)	192.5(14)	146.5(15)	184.5(15)	124(12)	230(22)	17(6)	74.5(10)	186(20)	0
ELGON DOWNS	1/(1)	NR	92.5(11)	220(17)	NR	121.1(9)	200.6(17)	216.2(7)	46.5(10)	440.5(15)	130.4(15)	6.1(-)
ADC KATUKE	NR	NR	77(9)	125(14)	124.5(14)	102.4(14)	148(18)	164.5(13)	41(6)	89(9)	203.5(13)	0
1996												
AMSDAO	49(7)	143(7)	119(9)	182(13)	98.9(14)	75.5(12)	87.5(17)	154.2(15)	162.5(10)	50.9(8)	60.1(7)	6(1)
KITALE MET	50(8)	66(7)	140.3(10)	223.7(15)	105.8(16)	68.2(11)	79.2(14)	201.9(18)	118.5(18)	47.9(12	63.7(9)	5.8(2)
ADC KATUKE	54(6)	2(1)	151.5(8)	121.5(11)	210.5(14)	108.5(12)	183.5(15)	123.5(16)	112.5(11)	29(5)	66(1)	0
ELGON DOWNS	47.7(7)	25(5)	88.5(9)	98.9(12)	94.2(12)	52.6(8)	137.2(14)	162.8(15)	64.4(11)	31.1(15)	**66.7(12)**	**0.4**

KEY

()	Denotes No of rainny days
NR	No report
(-)	No of rainny days not indicated

Table 17: Maize Prices per 90kg Bag sold through National Cereal and Produce Board (NCPB)

YEAR	ACHIEVED(Ha)	YIELD/HA(Bags)	MARKETED NCPB	THRO'PRICE Kshs/90Kg Bag
1985	59,479	40	1,800,000	297
1986	57,582	45	1,444,000	310
1987	69,631	40	1,090,000	333
1988	68,080	50	1,040,000	333
1989	68,350	50	1,134,000	363
1990	59,741	40	740,000	670
1991	63,090	45	1,020,000	670
1992	58,190	43	1,300,000	950
1993	65,676	28	1,400,000	920
1994	69,300	43		
1995	63,600	40		
1996	54,396	37		

Table 18: Target and Achieved hectors planted and yields attained

YEAR	TARGET(Ha)	ACHIEVED(Ha)	YIELD/HA(Bags)	TOTAL PRODUCTION(9C)Kg Bags)
1985	55,000	59,479	40	2,379,160
1986	60,000	57,582	45	2,601,190
1987	70,000	69,631	40	2,785,240
1988	70,000	68,080	50	3,404,000
1989	72,000	68,350	50	3,417,500
1990	70,000	59,741	40	2,389,640
1991	62,000	63,090	45	2,839,050
1992	64,000	58,190	43	2,502,170
1993	70,000	65,676	28	1,838,928
1994	70,000	69,300	43	2,979,900
1995	70,000	63,600	40	2,544,000
1996	64,000	54,396	37	2,012,652

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