# ASSESSMENT OF EFFECTS OF CLIMATE VARIABILITY ON MAIZE PRODUCTION IN MBEYA REGION

**BY**

**SULEIMAN JECHA HAJI**

**REG.NO. I45/84344/2012**

**izalgebraic@gmail.com**

**UNIVERSITY OF NAIROBI**

**DEPARTMENT OF METEOROLOGY**

**P.O.BOX 30197**

**Nairobi, Kenya**

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**[PGD]**

**AUGUST, 2013**

## Declaration

This research proposal is my original work and has not been presented for a degree in this or any other University.

**Signature ..........................**

**SULEIMAN JECHA HAJI** **Date ........................................**

Department of Meteorology

University of Nairobi

This proposal has been accepted for research study with our approval as University Supervisors.

**Signature .....................................**

**Prof. NG'ANG'A** **Date ........................................**

Department of Meteorology,

University of Nairobi

**Signature ......................................**

**Dr. KARANJA** **Date ........................................**

Department of Meteorology,

University of Nairobi

## DEDICATION

This work is dedicated to my treasures; Mwanaisha Haji Pandu. I thank her for being patients during my Postgraduate studies for almost one year.

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**Acronyms**

| | |
|---|---|
| EC | European Community |
| ET | Evapotranspiration |
| $ET_C$ | Crop Evapotranspiration |
| FAO | Food and Agricultural Organisation |
| GDP | Gross Domestic Product |
| IPCC | Intergovernmental Panel on Climate Change |
| SSA | Sub Saharan Africa |
| SST | Sea Surface Temperature |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| URT | United Republic of Tanzania |
| USA | United State of America |

**ABSTRACT**

The Mbeya Region in Tanzania is relatively fertile and contributes significantly to the national production of maize, the major food crop. Inadequate weeding is considered the main factor limiting maize yields by Croon *et al.* (1984).

This project work was undertaken to assess the effect of Climate variability on maize production in Mbeya region, with the aims of determining the relationship between climate variables and maize yields together with developing a maize yields prediction equation. An equation of this form may assist maize farmers and planners in decision making concerning application of farm inputs, storage, and marketing of produce and when to irrigate, spray and apply fertilizers.

The data of annual rainfall and mean maximum and minimum temperatures for this study was collected for the period ranging from 1972 to 2012. In the study area maize harvested in one season per year. The maize varieties used in Mbeya region are UH615. UH6303 and TMV2, these normally takes the period of 120 days (which is about five months) from Sowing stage to it's Maturity stage in which case the Planting process start from $20^{th}$ of December up to April and from there harvesting process can be taken place.

The maize yields data in Metric ton per hectors (MT/HA) was obtained from the Ministry of Agriculture Food Security and Cooperatives in Tanzania for the period ranging from 1990/1991 to 2011/2012. The climate data that was considered in the study includes annual rainfall (mm), mean maximum and minimum temperatures in degrees centigrade (°C).

The data was subjected to correlation and regression analysis with yields as the dependent variable and climate data as independent variables. The parameters that have significant correlation coefficients with maize yields were subjected to multiple regression analysis in order to develop the desired statistical regression model.

Fortunately for the correlation analysis of maize yields and climate variables, all parameters were considered correlated not significantly, this might be because those climatic parameters used in the study were not the limiting factors and due to the assumption made for the relationship was linear while not linear, hence the prediction equation for the maize yields was no longer developed.

## Chapter One

# 1 Introduction

## 1.1 Background of study

The well-being of large populations around the world depends on access, stability and availability of food (Schmidhuber and Tubiello, 2007). This is especially true in the developing world with predominant small land holders and subsistence farmers for whom the on-farm agriculture and off-farm agricultural labor provides the main source of food and income (Ito and Kurosaki, 2009). Besides a series of non-climate related factors, the vulnerability of these smallholder and subsistence farmers is greatly influenced by changes in climate (Morton, 2007).

Agriculture typically contributes around 25.8% of Gross Domestic Product (GDP) and comprises up to 40% of export earnings in Tanzania(URT, 2007); accordingly, the sector continues to drive economic growth. For example in 1992, it contributed 42. 9 % of the GDP (URT, 2001), more recently however, its contribution to the GDP has been severely reduced among other reasons due to climate-related agriculture Production failures. Because the agricultural system is largely-rain fed which is increasingly becoming unpredictable and unreliable with the continuing effects of climate change, the largest employer of the population is kept in jeopardy (Paavola, 2003). Worth noting, about 80% of poor Tanzanians live in rural areas where agriculture accounts for more than 75% of rural household incomes. In addition, agricultural holdings are typically dominated by small scale, subsistence farmers cultivating plots ranging from 0.9 to 3 ha (URT, 2007). Furthermore, agricultural system in the country is almost entirely targeted at food production.

The impacts of climate variability on agriculture sector in Tanzania include shifting in agro-ecological zones, prolonged dry episodes, unpredictability in rainfall, uncertainty in cropping patterns, increased weed competition with crops for (moisture, nutrients and light) and ecological changes for pests and diseases (Paavola, 2003, URT, 2007). Shortening and/or change of the growing season, a trend that has already been observed in Tanzania is seen as a direct consequence of the warming up and changes in rainfall. According to Funk et al. (2005), in Tanzania and East Africa at large, there has been a decrease in long-cycle crops and rainfall between March and May from 1996 to 2003. Even more worrisome, climate variability will require plants to adapt to the new situation, which keeps on changing (Paavola, 2003). Moreover, there is enough scientific evidence pertaining to pests, diseases and weeds intensifying with warming up of the environment.

The recent droughts and associated crop failures have led to severe hunger to many places in Tanzania that forced the government to organize food aid to the people. For example in Dodoma region there had been an 80% decrease in harvests as a direct result of poor or late arrival of rainfall. In 2005, the *Vuli*, short rains were very poor in many regions including areas where the rains are usually plenty, such as Kilimanjaro region. The shortage of the mentioned rains again triggered food aids to the starving people especially in coastal and north-east regions (URT, 2007). Moreover, in 2003, FAO described Tanzania as having a very high level of undernourishment, with 43% of the population being under nourished directly because of drought related food shortages (FAO, 2003). In 1992 for instance the average food supply in kcal/person/day was 2080, whereas by 2001 it had fallen to 1770. Similarly, in percentage terms, the undernourished comprised 35% of the population in 1992 and 43% in 2001.

Therefore, this study seeks to analyse the impact of intra- and inter-seasonal climatic variability on maize production (yields) in Mbeya region.

## 1.2 Problem statement

Rainfall is highly variable spatially and in total amount. In Tanzania, climate change posses its worst impact through interference with food security to the growing population. According to the Tanzanian government, 19% of the populations live below the food poverty line whilst 36% of the population lives below the wider poverty line (URT, 2005).

Tanzania is predicted to warm by 2 - 4 ºC by 2100, somewhat less than north-western Africa and South Africa (Paavola, 2008) Inner parts of the country are likely to experience higher temperature increases than coastal areas and cold and dry seasons will warm more than warm and wet seasons. Rainfall is predicted to decrease by 0 – 20 percent in the inner parts of the country(Paavola, 2008)

Changes in temperature, rainfall patterns and rainfall variability are likely to prolong dry seasons and to increase the severity of periodic droughts and thus decreased crop yields in several regions. This will be pronounced in the interior part of the country (Hulme et al., 2001; IPCC, 2001; Mwandosya et al, 1998). A shifts in mean and variability of temperature and precipitation and elevated atmospheric $CO_2$ concentrations, will significantly alter the conditions for agricultural production in Tanzania. The connection between climate change and crop growth and yields in Tanzania has not yet been studied and there is no information for agricultural planning regarding the extent of crop yield loss as result of 10 % and 20 % changes in rainfall amount or temperature increases of $1.5^0$C and $4.3^0$C. It is not clear whether this will lead to overall positive effects or, unless adaptive measures are taken (Antle et al., 2004) to potentially negative impacts on ecosystems services such as food production (Reilly and Schimmelpfennig, 1999).

## 1.3 Hypothesis of Study

In this study, the hypothesis to be tested is stated that changes in rainfall and temperature will lead to reduced maize production in Mbeya.

## 1.4 Objective of study

The main objective of this study is to assess the impacts of climate variability on Maize production in Mbeya region.

1. To determine temporal variability of rainfall and temperature over Mbeya region.
2. To determine effect of climate variability on maize production.
3. To predict maize production in Mbeya region.

## 1.5 Justification of study

Climate change is an important environmental, social and economic issue. It threatens the achievement of Millennium Development Goals aimed at poverty and hunger reduction, health improvement and environmental sustainability (UNDP, 2010). Over tropical region,

Agriculture is an important sector in Tanzania; it is termed the backbone of the country on account of its contribution to the Growth Domestic Product (GDP) and employment opportunities it offers. Agriculture typically contributes around 25.8% of GDP and comprises up to 40% of export earnings (URT, 2007). Predicted climate changes will significantly impact on food production. Warming and changes in rainfall will diminish water availability for crops and shorten the growing season. Warming will also increase crop losses due to weeds, diseases and pests. Regional predictions suggest that Tanzania may loose 10 percent of its grain production by 2080 (Parry et al., 1999; Downing, 2002).

Maize – a staple crop grown by half of Tanzanians and providing a third of their daily calorie intake – is going to be particularly hardly hit. Average maize yield is predicted to decrease 33 percent by 2075 if $CO_2$ concentrations will double and temperature increase by 2-4 degrees. Maize yields may decrease 80 percent in the Tabora-Dodoma region (Mwandosya et al, 1998)

Improved understanding of the influence of climate on agricultural production is needed to cope with expected changes in temperature and precipitation, and an increasing number of undernourished people in food insecure regions. Many studies have shown the importance of seasonal climatic means in explaining crop yields. Climate variability is expected to increase in some regions and have significant consequences on food production beyond the impacts of changes in climatic means.

However, little is known about the effects of current, observed extreme events (Easterling et al., 2000) on crop yields. Therefore, there exists a need for studies on the effects of climate variability on maize production to provide better advice to the government towards ensuring food security in the country.

## 1.6 Conceptual Framework

The present study assumes that if climate changes in terms of observed rainfall and temperature which are the main weather parameters, then maize production (yields) will decrease. This is shown in Figure 1.

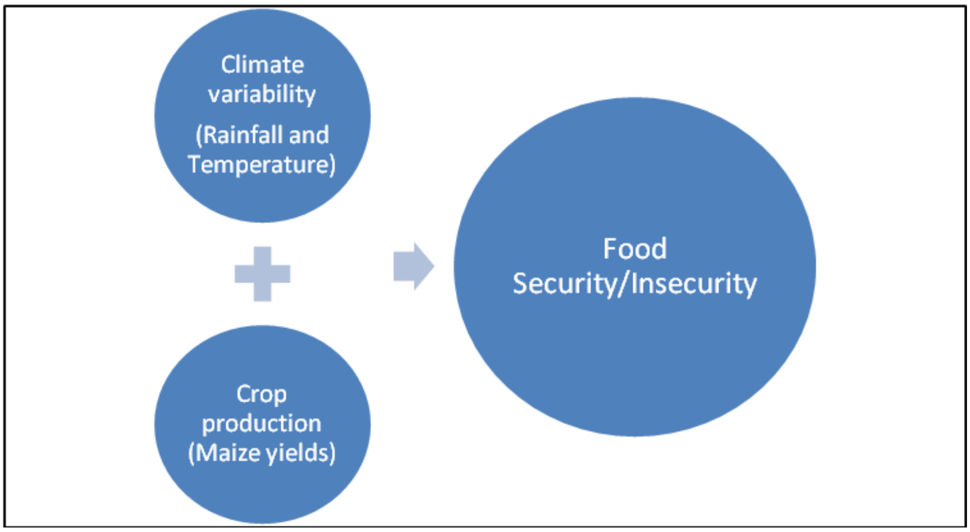


Figure 1: Conceptual Framework for the study

## 1.7 Area of study:

Mbeya region is located in the South Western Corner of the Southern Highlands of Tanzania. The Region lies between Latitudes 7$^o$ and 9$^o$31´ South of Equator, and between Longitudes 32$^o$ and 35$^o$ East of Greenwich. Mbeya region lies at an altitude of 475 metres above sea level with high peaks of 2981 metres above sea level at Rungwe higher attitudes. Mbeya shares borders with countries of Zambia and Malawi to the immediate South; Rukwa Region to the West; Tabora and Singida Regions to the North; while Iringa Region lies to its East, with Tunduma and Kasumulu in Mbozi and Kyela districts respectively being the main entries and/or exist into neighbouring countries of Malawi and Zambia.

### 1.7.1 MBEYA


Figure 2: The map of Tanzania showing location and neighbors

(Source: https://www.google.com/search?q=mbeya+map)

### 1.7.2 Land area, Climate, Soil and Vegetation

**1.7.2.1 Land area**

Mbeya Region has a total surface area of 63,617sq. kms out of which 1,858.7 sq.kms or 3.0 percent are covered by water bodies of Lake Nyasa, rivers Kimani, chimala, Igurusi, Kiwira, Lufilyo, Mmbaka, Songwe and Zira. The remaining 61, 759.0 sq.km is land area. Mbeya Region

is deemed to be one among the big Regions. It is occupies about 7.2 percent of the Tanzania mainland's total area of 881,289 sq.km (URT, nd).

Figure 3: Mbeya city as seen from loleza Mountain

(Source: http://www.tzonline.org/pdf/Mbeyadis.pdf)

#### 1.7.2.2 Climate

In regard to climate there are two key features which are temperature and rainfall. The Region Forms part of the southern highland zone of Tanzania which is greatly influenced by its physiographic and altitude. Mbeya climate is generally tropical with marked seasonal and altitudinal temperature with dry and rainy seasons. The rainy season is longer starts from October to May and the short dry season starts from June to September. The rainfall ranges from 650mm in Usangu plain and Chunya to 2,600mm per annum with high geographical, seasonal and annual variation on the northern shores of Lake Nyasa and in the highlands. The temperatures in the Region vary according to altitude but generally range from about 16$^{o}$C in the highlands to 30$^{o}$C in the lowland areas. Moreover, temperature differences are observed between day and night and may be very high with hot afternoons going up to 35$^{o}$C and chilly Nights going down to10$^{o}$C. (URT, nd).

#### 1.7.2.3 Soil and vegetation

In most arable areas, soils are commonly of moderate fertility, caurse or medium textured and varying from sandy loams, alluvial solids to cracking rocks. Although a large area of the region is cultivated, large tracks of land are still covered with natural vegetation such as "Miombo" (Broschystegion,Julbernardia) woodland. Areas with rains between 800-1200 mm.per annum favour the growth of Miombo woodland, while areas with less rains especially in the North of the region support the growth of wooded grassland and bushlands of dense thickets- of acacias and thorny trees. Those areas with higher rainfall e.g. Rungwe, Kyela and South-East Ileje support forests, often evergreen and bamboo trickers-xcept at the highest elevations, where afro-alpine grasslands occur.

#### 1.7.2.4 Phenological Phase of Maize Crop

For standardization of definitions, maize researchers developed a guide for identifying different growth stages of maize. Not all plants in a field reach a particular stage at the same time. Therefore, researchers assume that the crop reaches a specific stage when at least 50% of the plants show the corresponding features.

Standardization of definitions allows researchers to relate problems to specific growth stages. Researchers can also compare the phenology of maize under different environmental conditions and experimental treatments.

Researchers divide growth stages into two broad categories, namely:

- vegetative (V)
- reproductive (R)

Additionally, growth stages can be grouped into four major periods (see Table 1 for more details):

- Seedling growth (stages VE and V1)
- Vegetative growth (stages V2, V3... Vn)
- Flowering and fertilization (stages VT, R0, and R1)
- Grain filling and maturity (stages R2 to R6)

**Table 1:** Phenological Phase

| **Stage** | DAS* | Features |
|---|---|---|
| VE | 5 | The coleoptile emerges from the soil surface |
| V1 | 9 | The collar of the first leaf is visible. |
| V2 | 12 | The collar of the second leaf is visible. |
| Vn | | The collar of the leaf number 'n' is visible. The maximum value of 'n' represents the final number of leaves, which is usually 16-23, but by flowering, the lower 4-7 leaves have disappeared. |
| VT | 55 | The last branch of the tassel is completely visible. |
| R0 | 57 | Anthesis or male flowering. Pollen shed begins |
| R1 | 59 | Silks are visible. |
| R2 | 71 | Blister stage. Kernels are filled with clear fluid and the embryo can be seen. |
| R3 | 80 | Milk stage. Kernels are filled with a white, milky fluid. |
| R4 | 90 | Dough stage. Kernels are filled with a white paste. The embryo is about half as wide as the kernel. The top part of the kernels are filled with solid starch |
| R5 | 102 | Dent stage. If the genotype is a dent type, the grains are dented. The 'milk line' is close to teh base when the kernel is viewed from the side in both flint and dent types. |
| R6 | 112 | Physiological maturity. THe black layer is visible at the base of the grain. Grain moisture is usually about 35% |
| | | * DAS: approximate number of days after sowing in lowland tropics, where maximum and minimum temperatures may be 33° C and 22° C, respectively. In cooler environments, these times are extended. |

Different Vegetative growth stage can be seen in the figures 4 and 5 below;

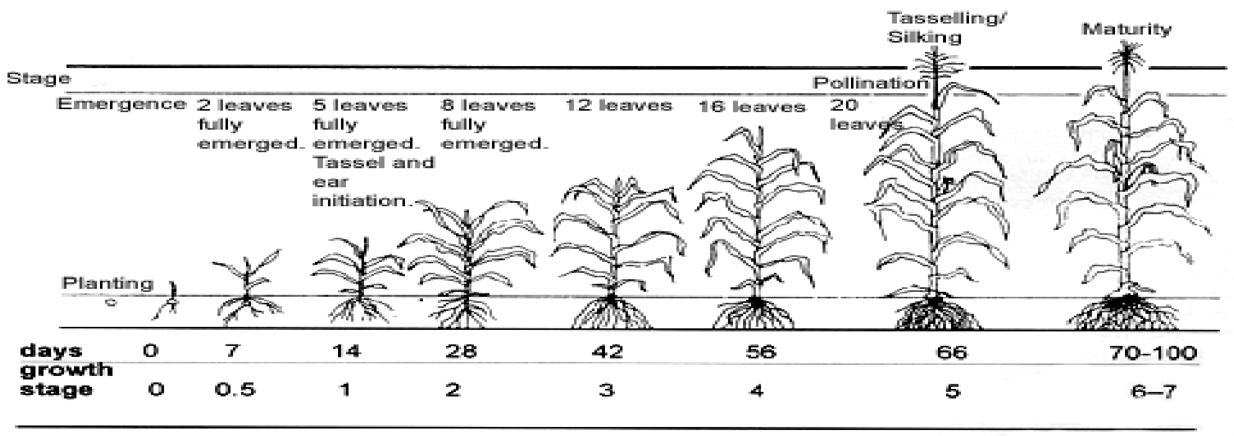


Figure 4: Growth stage of Maize crop with the approximate number of Days

(Source: www.google.com)

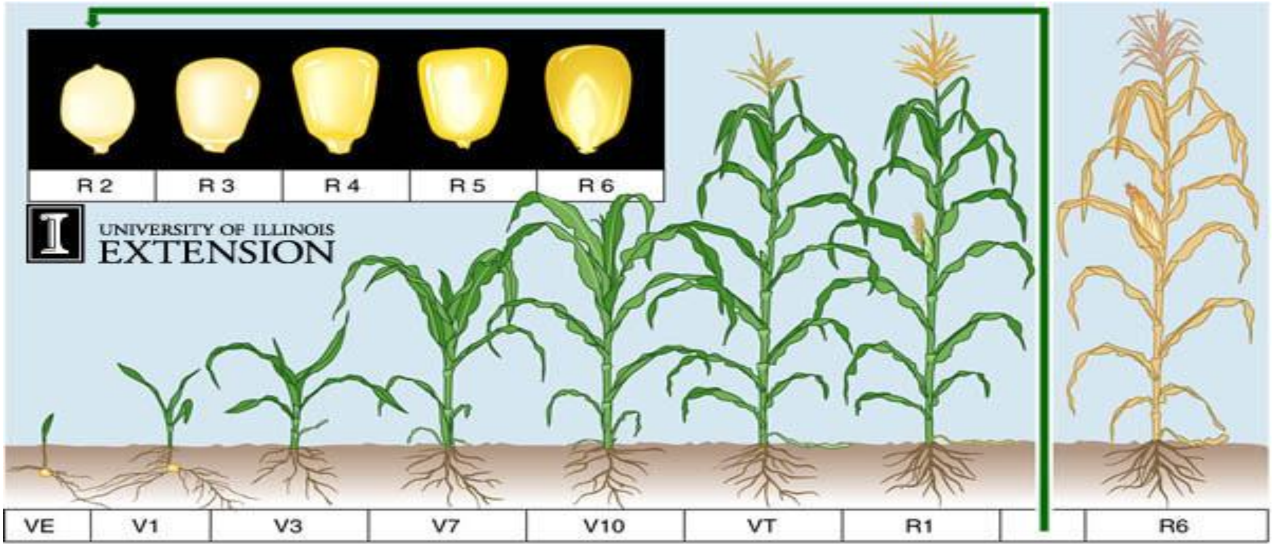


Figure 5: The two broad categories of Growth stages; Vegetative (VE to VT) and Reproductive (R1 to R6)

**(Source: www.google.com)**

# Chapter two

# 2 Literature review

## 2.1 Climate Change and Crop Production

As weather is a major influencing factor on crop growth, climate change will have an impact on agricultural production. A number of studies have investigated several aspects of the impact of climate change. They use different methods depending on their suitability to the task at hand. There is a large dispersion in results across studies, depending on the crops, the regions and/or climate change scenarios envisaged. Nevertheless, limitations are associated with each method which influences the reliability of the impact estimates (Blanc, 2011).

Many studies predict an adverse impact of climate change on farm outcomes. However, farmers' adaptation strategies are likely to alleviate the potentially damaging effect of global warming. Smit et al. (2000) review several adaptation definitions. These definitions imply that adaption refers to any societal or structural adjustment aimed at reducing the adverse effect of climate change. According to IPCC (2001) adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages. In 2003 , unusually high temperatures during the summer reduced food production (and killed over 50,000 people) with cereal and fruit harvests dropping drastically in Europe, especially in Italy and France where maize production fell by more than 30% (Ciais et al., 2005; Battisti and Naylor, 2009).

Yanda (2005) showed that wider global climate change trends are greatly reflected in Tanzania's climate. Because of her geographical location and the topographical characteristics, the country offers the best opportunity to study and further understand global climate trends. Recent researches have suggested that, alongside other East African countries, climate change has badly affected the country. Deteriorating water quality and quantity, loss of biodiversity and declining agricultural productivity due to climate change, are no longer potential threats but rather threats that have already struck and caused Tanzanians repeated misery

Several recent studies have analysed the impact of observed climate change. Global annual temperatures have already increased by 0.4°C since 1980 (Lobell and Field, 2007). An impact analysis of climate change since the early 80s was performed by Carter and Zhang (1998). The authors use an aridity index combining mean monthly temperature and total monthly precipitation to evaluate the impact of climate on grain in China. They considered two sub-periods, 1978-1984 and 1985-1992, during which two different government policies were introduced to regulate the grain sector. Their findings indicate that the climate had different impacts during the two periods. Climate accounted for 1.3% of the growth in grain production in the first sub-period, and only 0.4% in the second sub-period. The authors argue that the 0.9 percentage point difference in grain production growth rate between the two periods is explained by better weather in the first period than in the second period.

Study by Mwandosya, et al. (1998) show that in Tanzania mean annual temperatures and average daily temperatures will rise by between 2 to $4^{o}$C by 2075 as a direct consequence of climate change (URT, 2003). Putting Tanzania into a wider African context however, it is projected to warm up less than many countries notably North-western and Southern Africa (URT, 2007). Interestingly, the interior parts of the country are projected to face higher temperature increases than coastal areas whilst cold and dry seasons will warm more than warm and wet seasons

According to IPCC (2001) report indicated that apart from temperature data, change in rainfall patterns is likely to be more torturous and with immediate severe effects. In Tanzania, rainfall models indicate that rainfall will become less predictable and their intensity more volatile. Tanzania expects to have a decrease in rainfall by between 0 to 20% in the inner parts of the land. Northeast, southeast and the Lake Victoria basin however, expects to have a total increase in rainfall by between 20 to 50% (Hulme, et al., 2001). Such major changes in rainfall patterns will inevitably have severe consequences to the society, some of which (repeated droughts and floods) are already happening.

Other studies (URT, 2003; Paavola, 2003) on climate change in Tanzania show that there will be an increase in extreme weather events. The extreme weather events in Tanzania are associated with flooding, droughts, cyclones, tropical storms all of which are projected to be more intense, frequent and unpredictable. The vulnerability of the country to extreme weather events can specifically be looked at in terms of the recurring drought conditions and the recent El Niño seasons of 1992-1993 and 1997-1998. In terms of impacts to the society, the named El Niño episodes were very significant because they were accompanied with heavy socio-economic losses. The episodes resulted into nationwide power blackout and rationing, food shortages and sky rocketing prices, massive losses of livestock and agricultural crops.

Winch (2006) notes that precipitation is a key determinant of crop growth and yields in rainfed areas. Plants assimilate water through their roots and transpire it through small pores in their leaves called stomata. Water lost via transpiration has to be replaced by water available in the soil (soil moisture) to enable plants to grow. When soil moisture is insufficient to cover the plant's water needs, water stress occurs and plant growth is hindered.

According to Cothren et al. (2000), plants have different water requirements depending on their physiology, phenological stage and the climatic zone where they are grown. As small plants have a smaller leaf surface area than larger plants, smaller plants transpire less and thus need less water. Some plants have particular water needs during critical growth stages (Smith, 1920). In hot, dry, windy and sunny areas, plants transpire more, and thus have higher water requirements, than in cool, humid, cloudy and windless areas (Critchley and Siegert, 1991).

Insufficient or excessive water supply can hinder plant development. The impact of droughts and floods on crops yield differs across plants. Some crops resist droughts better than others due to their physiology. For example, cassava has long roots which allow it to reach moisture deeper in the soil and also limits transpiration via partial stomata closure and a small leaf canopy (El-Sharkawy, 2007).

Went, (1953) defined temperature as a measure of the intensity of heat energy. Temperature influences plant growth as it affects physiological processes such as photosynthesis, transpiration, respiration, germination, and flowering. Air temperature is a more important for crop growth than soil temperature (Mavi and Tupper, 2004). Unless otherwise mentioned, the term temperature employed in the followings section refers to air temperature.

Mavi and Tupper (2004) noted that plants suffer from temperature stress if they are exposed to excessively high or low temperatures. For most crops, death occurs when the temperature rises above 50°C. Low temperature stress is also detrimental to plant growth and even a light frost can kill some crops (Winch, 2006). Generally, crop growth is conditional on temperatures between 10°C and 40°C (Mavi and Tupper, 2004). However, heat requirements differ among crops and sometimes also among varieties of the same crop. Heat requirements also differ across crop physiological development stages.

Corobov (2002) also studied maize yields and found that temperature and precipitation appear to be responsible for 40% of maize yield fluctuations. A similar finding is estimated by Lobell and Field (2007) at the world level. They find that weather during the period 1961-2002 is responsible for 47% of year-to-year change in maize yields. Temperature is estimated to be responsible for 25% of maize yield trends according to Lobell and Asner (2003), who consider a 17-year period from 1982 to 1998 in the United State of America (USA). They estimate a 17% decrease in maize yields due to a 1ºC warming during the growing season. No significant effect of precipitation and radiation is found.

A statistical analysis of climate change impacts on five major United State (US) crops conducted by Chen et al. (2004) also establishes a detrimental impact of temperature on maize yields. However, the estimated impact is greatly dependent on the functional form estimated. The 24 Authors determine that maize yields decrease by 0.24% due to a 1% temperature increase when using a linear functional form. When using a Cobb-Douglas specification, the corresponding decrease is 2.98%. Additionally, the authors find that maize yield variability increases with temperature: a 1% temperature rise increases maize yield variance by 7.51% and 0.89% respectively in the linear and Cobb-Douglas functional form.

Hall (2001) acknowledges that solar irradiance is specific to each location's latitude and is affected by the position of the sun, day length, cloudiness, turbidity, altitude and land slope. Solar radiation is intercepted by plants through their leaves and is essential for photosynthesis (Walker, 2006). However, light requirements differ across crops and growth stages. "Sun plants" such as most cereals, require solar radiation during the whole growing period

A study by Allen et al. (1998) identified evapotranspiration (ET) rate as a comprehensive indicator of weather conditions. ET is the combination of the loss of water from soils (by evaporation) and from crops (by transpiration). This quantity of lost water (expressed in millimetres (mm) per day) has to be compensated by an equivalent amount of new water to enable plants to develop properly, known as the crop water requirement. If rainfall and/or irrigation do not meet ET demand, or crop water requirement, a water stress occurs, which reduces crop yields (Maman et al., 2003).

Cothren et al. (2000) notes that crop evapotranspiration (ETc), which represents crop water use, considers plant characteristics in addition to weather factors. ETc is obtained by multiplying ETo by a crop coefficient. As the rate of transpiration depends on leaf surface, this coefficient varies depending on the type and variety of plant considered. Moreover, as water requirements change as plants develop, ETc is calculated for each phenological stage. Cultural practices such as fertilization and environment influences (e.g. pests and diseases) can be used to determine adjusted crop evapotranspiration..

Rosenzweig and Iglesias (1994) noted that crop models can help to facilitate communication between crop researchers and decision-makers on the social effects of climate change and crop yield variability. The threats and opportunities induced by climate change will force farmers to perform risk analyses. These new conditions will continuously evolve with the probabilities of specific weather conditions. Consequently, farmers will have to permanently adapt their production techniques and productions to the new conditions. Adaptations include optimized farmers' decisions about their portfolio of crop and animal production (products and techniques). Possible adaptation strategies for marginal areas may mean that growers may have to switch to more water efficient crops such as sorghum or millet or change production entirely from crops to livestock.

Agriculture, and especially crop production, is heavily dependent on weather events in Sub Saharan Africa (SSA), where 97% of agricultural land is rainfed (Rockström et al., 2004). Crop production and food security are therefore affected by changes in climate. Most studies have focused on measuring the impacts of changes in climatic means on crop yields (Lobell et al., 2008; Tao et al., 2008). However, in addition to changes in climate means, climate variability is expected to increase in some regions in the future, including the frequency and intensity of extreme events (IPCC, 2007). Some have proposed that changes in extremes will have a more adverse impact on crop production than changes in mean climate alone (Porter and Semenov, 2005; Morton, 2007; Tubiello et al., 2007).

## 2.2.0 AGRO – ECOLOGICAL CONDITIONS OF MAIZE CROP

Climatic conditions as well as geological features have been the base of identifying different agro-ecological zones in Mbeya Region. Basically the Region has three distinctive agro ecological zones.
In this section the general agro-ecological effects of rainfall, altitude, temperature and fertilizer requirements on the Maize productivity are presented, as shown below:

1. **High Potential Zones:-**

It includes areas with high rainfall and fertile soils, with a lot of agricultural production. These are the high density populated areas i..e. South Usangu Plains, Central Mbeya Plain, Poroto and Ilembo Highlands, East Ileje,West Rungwe Plain, East and Central Rungwe, South Rungwe/NorthKyela, and the South Kyela. Lowland.

2. **Medium Potential Zones:-**

Areas that fall under Medium Zone do experience moderate rainfall and they include Rukwa Valley, Mbozi/Ileje Plateau, and North Usangu Plain.

3. **Low Potential Zones:-**

These include Central Chunya areas and Msangaji Plateua. Usually rainfall is unreliable and soils are less fertile.

**Highlands Zone**

The Highlands zone lies at an altitude of 1,500 to 2,400 metres above sea level and covers the areas of Central Mbeya Plain, Mbeya Highlands, Ilembo and Poroto Highlands East Ileje and West Rungwe Plain, East and Central Rungwe, South Usangu Plain and North Kyela and Southern parts of Rungwe. The Highlands have cool temperatures and receive rainfall exceeding 2,500 millimenters per year. Crops cultivated include, maize, groundnuts, beans, wheat, potatoes, coffee, bananas, tea, cocoa. Dairy farming is common.

**Midlands Zone:**

The Midlands zone lies at an altitude of 800 to 1500 meters above sea level and embraces the areas of Rukwa Valley, Mbozi/Ileje Plateau, Southwest of Mbozi, and North Usangu Plain. Rainfall is highly variable and increases with increasing altitude, ranging from less than 700 mm. per year at North Usangu Plain to 1,700 mm. per year at the Mbozi/Ileje Plateau.
In the Midland zone people prefer cultivating maize, sorghum, finger millet, cotton, cowpeas, groundnuts, cassava, beans and some paddy. Cattle and goats are also common animals in the zone.

**Lowlands Zone:**

The Lowlands zone lies at an altitude of 500 metres to 1000 metres above sea level occupying mainly the areas of North Chunya Plain, Central Chunya and Msangaji Plateau and Kyela Lowlands. Temperatures are warm with annual rainfall of less than 1000 mm. However, the Kyela Lowlands sometimes get rainfall as high as 2500mm. per year. Several crops thrive well in the Lowlands zone, for instance, tobacco, maize, sorghum, finger millet, cassava, groundnuts, cocoa, cashewnuts, palm oil, paddy and bananas. Cattle, goats and sheep are reared as well.

**Fertilizer:**

In the southern highlands Nitrogen and Phosphorus are the major limiting nutrients for maize production. Studies have shown that improved varieties require substantial quantities of mineral nutrients for their vegetative and grain development, for instance, a crop that produces 5-6t/ha will have removed 100-150 kg of nitrogen and 40-50kg of $P_2O_5$ per ha from the soil (Prasad 1978). The use of both inorganic and organic fertilizers can lead to high yield. Research undertaken at Uyole, showed that when low doses N and P (i.e 40 and 15 kg/ha, respectively) supplemented with 20 t/ha of farmyard manure (FYM) the grain yield was 7.1 t/ha compared with 4.03 t/ha when the same rates of N and P where used alone and 5.12 t/ha when FYM at the rate of 20 t/ha was used alone (Lyimo and Temu 1992).

Fertilizer recommendation is based on soil types and nutrients deficiency. For basal application TSP and NPK at the rate of 100-400 kg/ha are recommended for top-dressing CAN at the rate of 200-400-600, SA at the rate of 250-500-750, and urea at the rate of 100-200-350 kg/ha are recommended.

Chapter Three

# 3 Data and Methods

In this chapter, various methods will be used in this study so as to achieve the objective as stated in section 1.4. These include data quality control and estimation of missing data, time series analysis and correlation analysis. These methods are briefly discussed in following sections:

## 3.1 Data

### 3.1.1 Climate data

Temperature and precipitation datasets for a period of 40 years (1972 -2012) were obtained from the Tanzania Meteorological Agency. Monthly values of precipitation and mean maximum and minimum temperatures were available from Mbeya and Uyole Agrometeorological stations from 1970 to 2012. Table 2 and Figure 2 shows locations and coordinates of the area used in the study

**Table 2:** Location of stations used in the study

| Station | Latitude | Longitude |
|---|---|---|
| Mbeya | $8.9000^0$S | $33.4500^0$E |
| Uyole | $08^0 55'$S | $33^0 32'$ E |

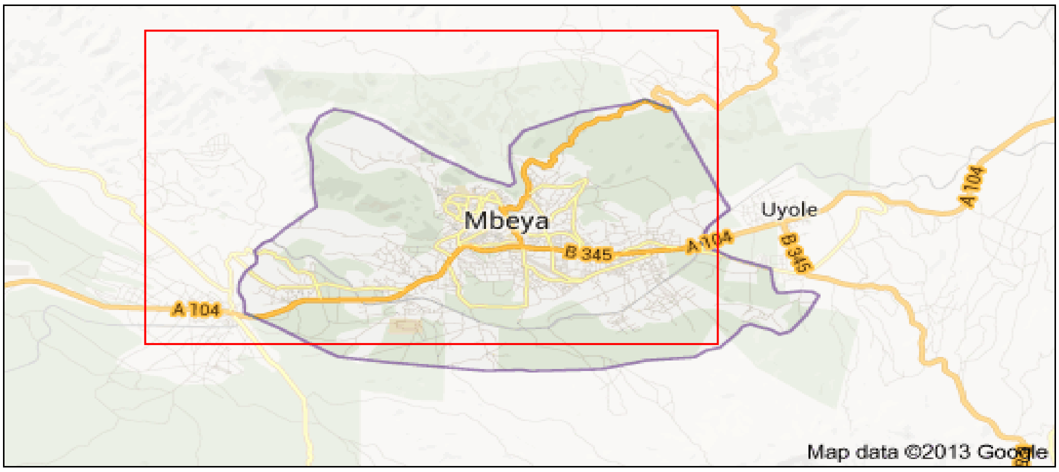


Figure 6**:** Mbeya regions showing the domain of study

(Source: https://www.google.com/search?q=mbeya+map)

### 3.1.2 Maize Yied

Maize production data was sought from the Ministry of Agriculture Food Security and Cooperatives, Tanzania. It covered the period 1990 to 2012

## 3.2 Methodology

### 3.2.1 Data Quality Control

The consistency of rainfall data, temperatures and maize yield data was tested using single mass curve method while the missing data were estimated using the arithmetic mean method. The effect of past climate on maize production was analysed at two stations in Mbeya region on seasonal and annual time scales.

#### 3.2.1.1 Estimation of Missing Data

There are several methods of estimating missing climatic data record. Type of method depends on whether the missing data are temporal or spatial data. Temporal resolution is good for annual, monthly, daily and hourly depends on the length or amount of missing records. In some cases, certain methods (e.g. methods based on time series analysis) can only be applied on the available record length (Salas, 2006). Apart from normal ratio, inverse distance method, correlation and regression, this research employed arithmetic mean method which is the simplest and most objective method of estimating missing data. It involves replacing the missing data with the average or the mean for a given station and it is given by the following relationship;

$$X_m = \left(\frac{\overline{X}}{\overline{Y}}\right) Y_m \qquad (1)$$

Where

$X_m$ , is the missing records at station X.

$\overline{X}$ , is the long term mean for the station with missing data in certain year and month.

$\overline{Y}$ , is the long term mean for the station with complete data.

$Y_m$ , is the corresponding records at station Y having complete data

#### 3.2.1.2 Data Homogeneity

Reliable data which are free from artificial trends or changes are important in any research. Data reliability was checked by applying homogeneity test which involved comparison of data from one station to its surrounding stations. Single mass curve and moving average plots was used in this research to test for homogeneity. The linearity of the plots indicated homogeneity of the data, otherwise heterogeneity was be depicted by non-linear plots.

### 3.2.2 Temporal variability of Rainfall and Temperature

Observed data sets were used to analyse variability of the datasets. Climatologically data often contains noticeable cycles which are apparent in monthly data (seasonal cycles), while daily cycles can be observed in hourly measurements. Although there are other cyclic variations at longer time-scales, such as modes of climate variability, they are not regular (i.e. with fixed periods) as seasonal variation (WMO, 2000). Study of seasonal variation required regular or nearly regular observations, e.g. one month or one season, more frequent observations. This was achieved through time series analysis to detect the trend in climate variables. Trend analysis presents the long term movement of the time series. Trend patterns can be derived from graphical and statistical techniques (Ogallo 1980, 1981b; Omondi 2005; Muthama et al., 2008).

In this study, time series analysis was used to investigate the trend of climate and maize production over Mbeya region. Many time series depict characteristic variations. Analyses of such variations constitute time series analysis. A time series is a collection of observed data at equal intervals of specified time. From a statistical point of view, the study of climatic variability is a problem of time series analysis (Raziei, 2005). Statistical evidence of persistence in such time series is equated with evidence of unquestionable climatic fluctuations and said to be dependent. A time series is not statistically independent in many cases, but is comprised of persistence, cycles, trends or other non-random components. When the nature of the trend is subject to change over short intervals of time, it is termed local trend, or, on the other hand, it can be visualized as global trend that is long lasting (Rai, et al., 2010)

The graphical method involves the plotting of scatter diagram where various variables are plotted against time. The scatter diagram shows neighboring points connected to generate a time versus data points graph. At times, a time series can be smoothed out with the intention of showing the natural trend of the center of mass of the data. Smoothing always involves some form of local averaging of data such that the non-systematic components of individual observations cancel out. However, graphical method is highly subjective and has the weakness of dependency on visual judgment (Ogallo, 1977 and Omondi 2005)

### 3.2.3 Effects of seasonal variations of rainfall and temperature on maize production

The effects climate variability on maize production was assessed using correlation analysis as shown in equation 2. This was meant to determine the degree of relationship between climate variables and maize crop yield.

$$R_{xy} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 \cdot \frac{1}{n}\sum_{i=}^{n}\left(y_i - \bar{y}\right)^2}} \text{..........................................(2)}$$

Where, $R_{xy}$ is the correlation coefficient, n is the sample size, $X_i$ and $Y_i$ are the variables being correlated and $\bar{x}$ and $\bar{y}$ are the mean values of variables being correlated.

The computed correlation values were tested for statistical significance at 95% confidence level using the student-t- test as shown in equation 3. Only those parameters corresponding to statistically significant correlation coefficient were considered in the development of the regession equation.

$$t_{n-2} = r\sqrt{\frac{n-2}{1-r^2}} \text{..................................(3)}$$

In equation 3, t is the value of the student-t-test *n* is the number of observations and *r* - is the correlation being tested

### 3.2.4 Prediction of Maize production in Mbeya region

#### 3.2.4.1 Multivariate Regression Model

This is a parametric test that assumes that the data are normally distributed. Multiple linear regressions is a method used to model the linear relationship between a dependent variable and one or more independent variables. The dependent variable is sometimes also called the predictand, and the independent variables the predictors. Multiple linear regressions is based on least squares: the model is fitted such that the sum-of-squares of differences of observed and predicted values is minimized. The model expresses the value of a predictand variable as a linear function of one or more predictor variables and an error term.

$$Y_i = B_1(x_{i,1}) + B_2(x_{i,2}) + \dots\dots\dots\dots.. + B_n(x_{i,n}) \qquad (4)$$

In equation 4, $B_n$ is coefficient on the n$^{th}$ predictor, $x_{i,n}$ value of the n$^{th}$ predictor, $n$ is the total number of predictors and $Y_1$ predictand (maize production). The predictors used included Annual rainfall, Mean maximum and minimum temperature for Uyole station.

## Chapter Four

# 4 Results and Discussion

## 4.1 Estimation of missing data

There were few missing data in all the stations used at different times which were estimated using arithmetic mean method as discussed in Section 3.2.1.1. Results from the single mass curves are presented in figures 6 - 8.

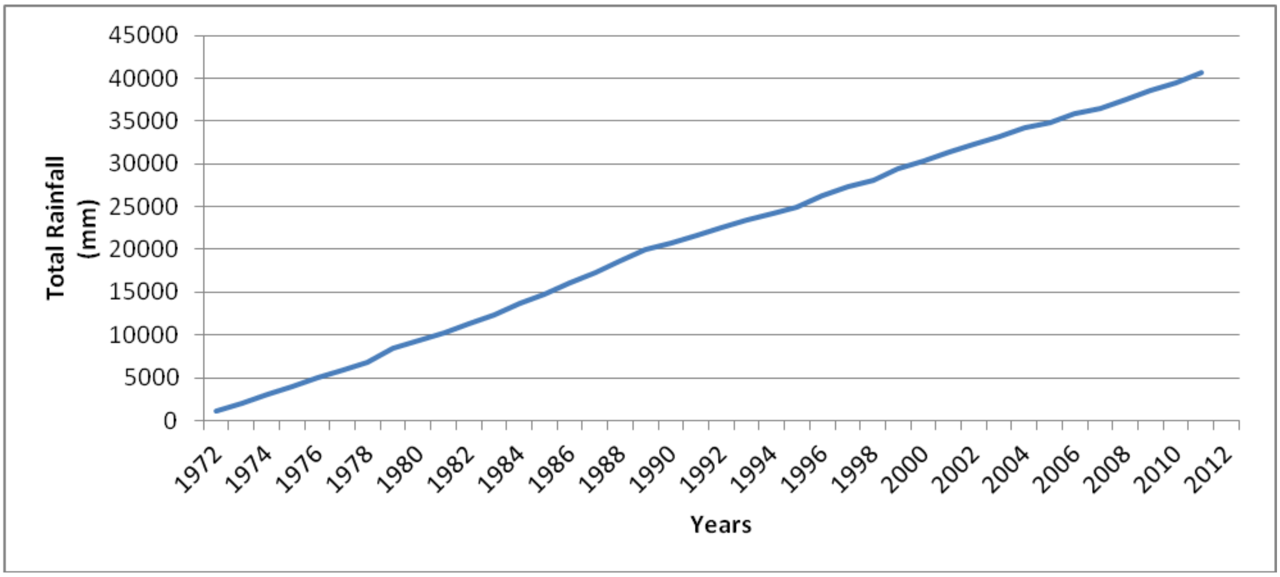


Figure 6: Single mass curve of cumulated Total rainfall over Uyole Agro-meteorological stations.

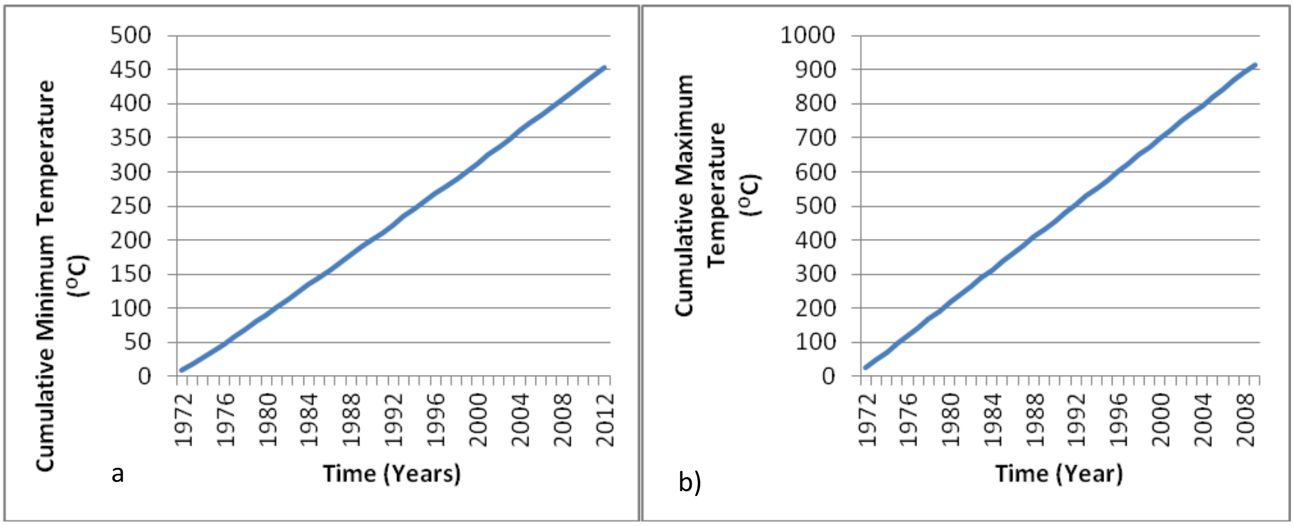


Figure 7: Single mass curve of cumulated (a) Minimum and (b) Maximum temperature over Uyole Agro-meteorological station.

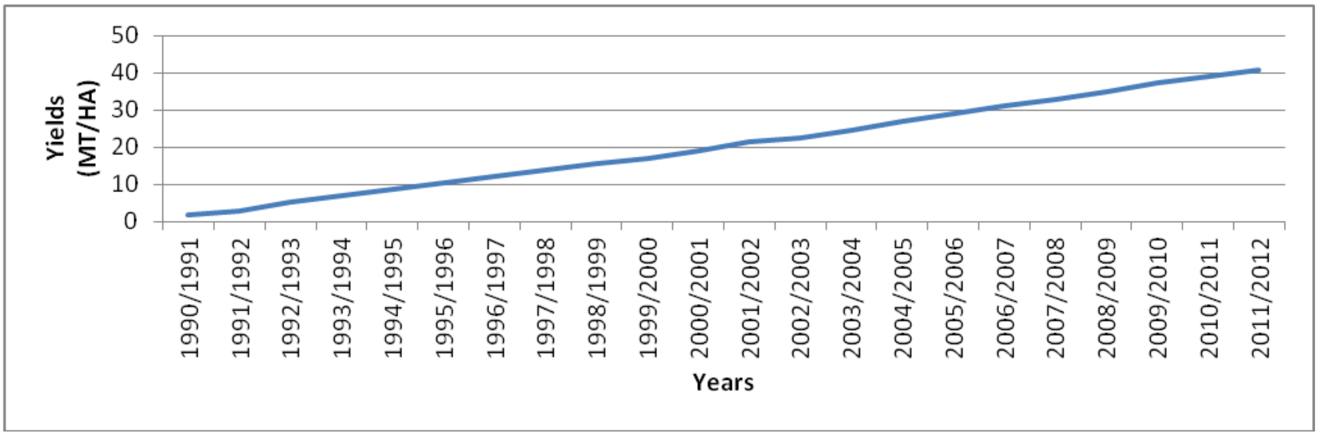


Figure 8: Single mass curve of cumulated maize yield over Mbeya region

Linear graphs of mass curves indicated straight fitted to montly cumulative rainfall, temperature and maize yield records over Mbeya region. This indicated homogeneity of the records used in the study and thus good quality data records that was used for further analysis. The homogeneity test for rainfall totals and maize yields was less smooth compared to both minimum and maximum temperature due to the fact that rainfall and maize yield datasets are discrete while temperature records are continuous.

## 4.2 Variability of Rainfall, Temperature and Maize Yields over Mbeya region

This section presents variations of rainfall, temperature, and maize production based on graphical analysis.

### 4.2.1 Temporal variability of Rainfall, Temperature and Maize Yields

The graphical method provided visual presentation of the patterns of the time series of observed data for various stations in the study area. The graphical method that was employed involved plotting of the original unsmoothed time series. Some of the patterns of unsmoothed time series with a fitted trend line and locally weighted regression are shown in Figure 9 - 11

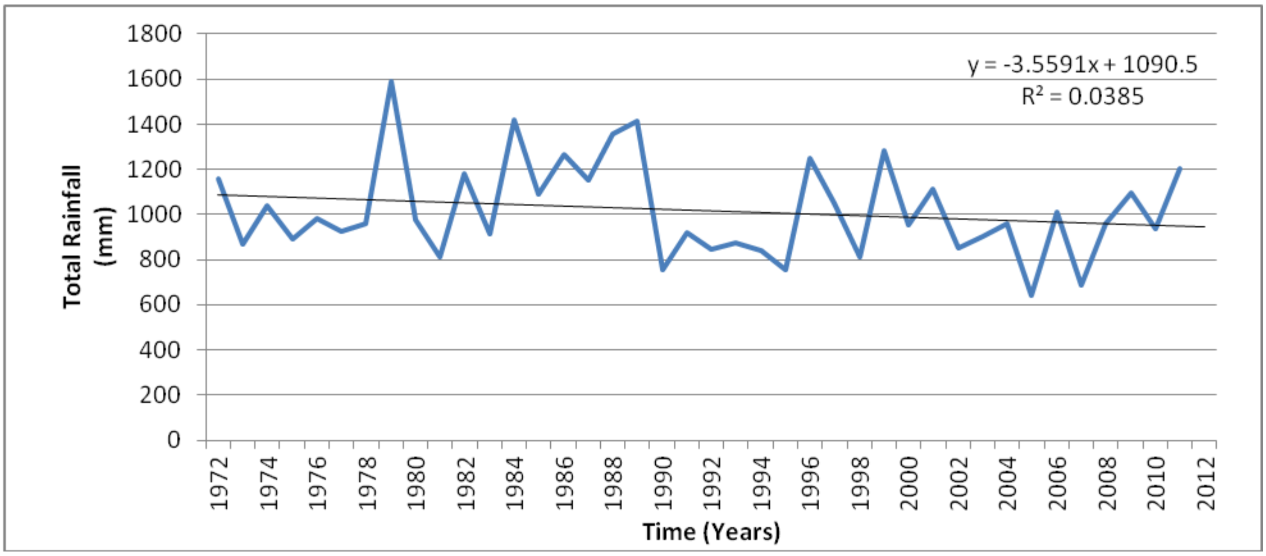

Figure 9: Time series of Annual total rainfall over Uyole Station.

In figure 9, annual total rainfall over Uyole stations were noted to be decreasing over time. Similar concerns of decreasing rainfall were found by Kangalawe et al. (2011) that showed annual rainfall in Mbeya to have been decreasing since the 1980s.

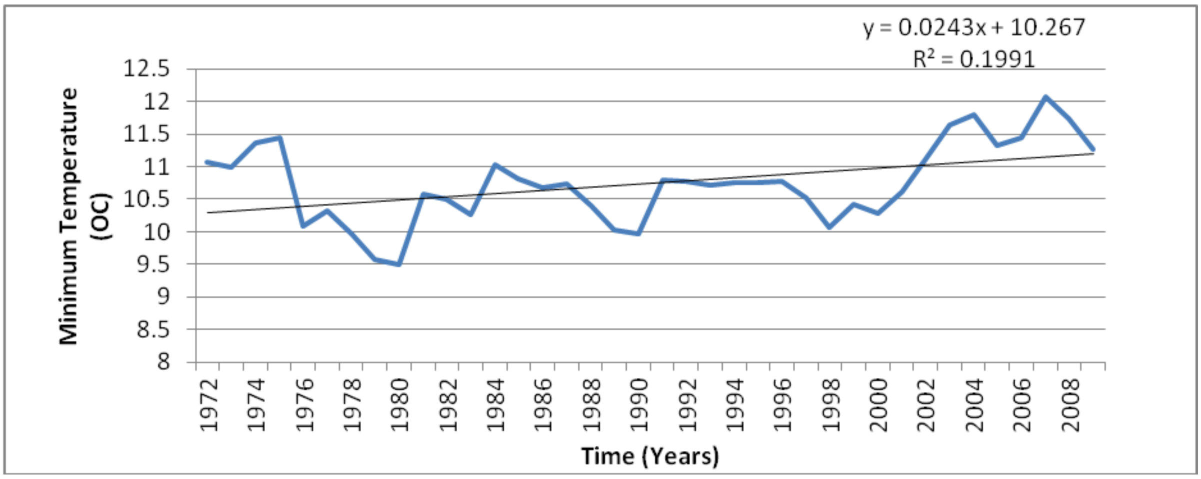


Figure 10: Time series of Minimum temperature over Uyole station.

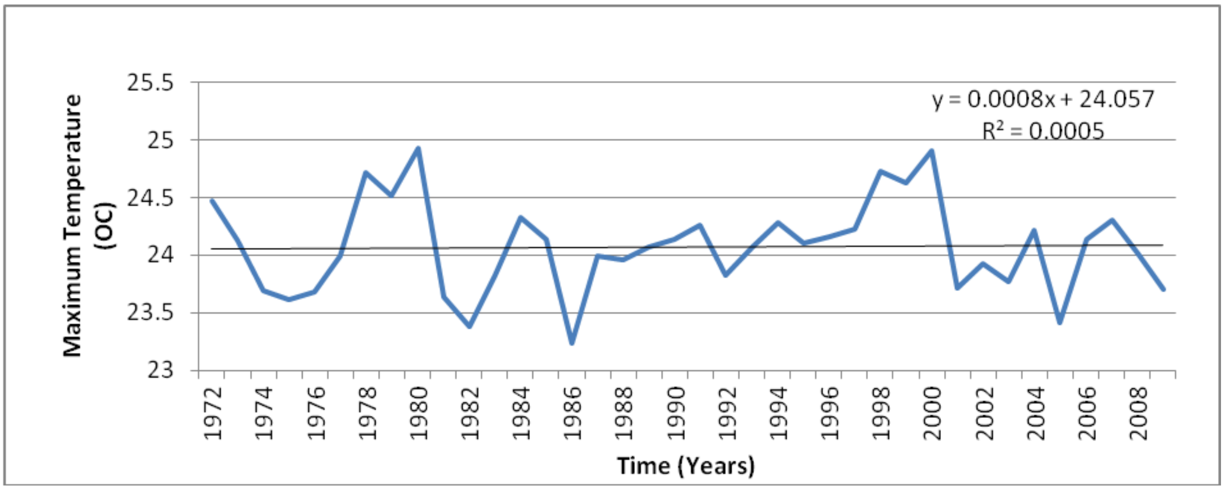


Figure 11: Time series of Maximum temperature over Uyole station.

In figure 10 and 11, both minimum and maximum temperatures were observed to be increasing over Uyole station.

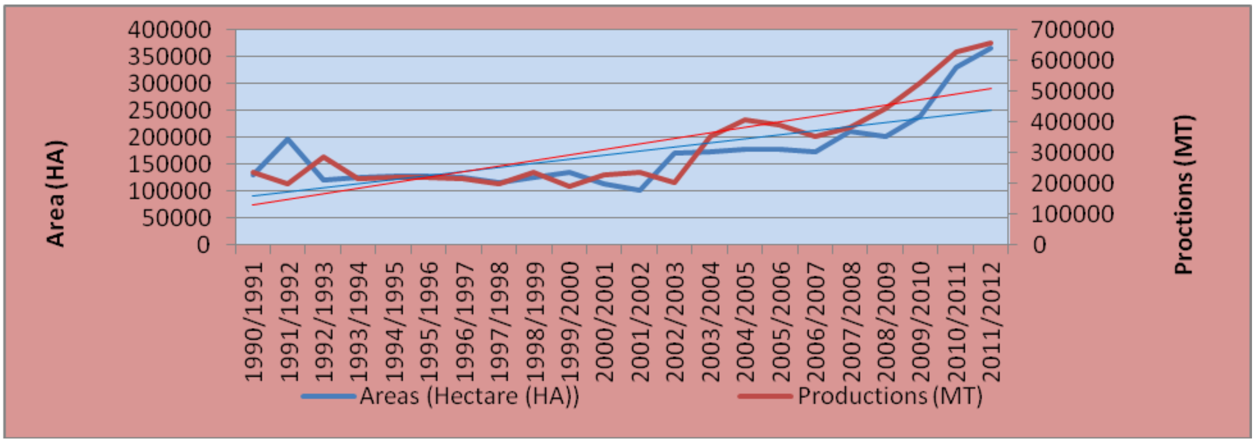


Figure 12: Time series of area planted and production of maize over Mbeya region

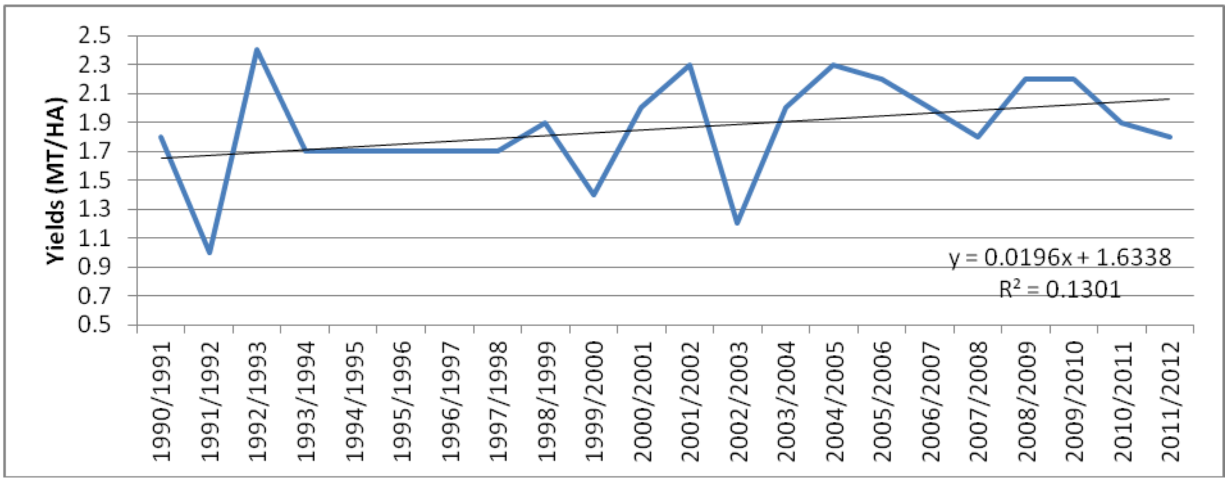


Figure 13: Time series of Maize yields over Mbeya region

In figure 12 and 13, time series of area planted, production and maize yields over Mbeya region showed an increasing trend. However, a study by Jones and Kiniry (1986) indicate that estimates of the affect of climate change on maize yields based on simulation results showed lower yields as a result of higher temperatures and decreased rainfall at 33% over the entire, with the southern highland areas of Mbeya estimated to have decreases of 10-15% in maize yield.

### 4.2.2 Seasonal variation of Rainfall and Temperature

The graphical method provided visual presentation of seasonal variation of observed data for Uyole station in the study area presented in figures 14 and 15

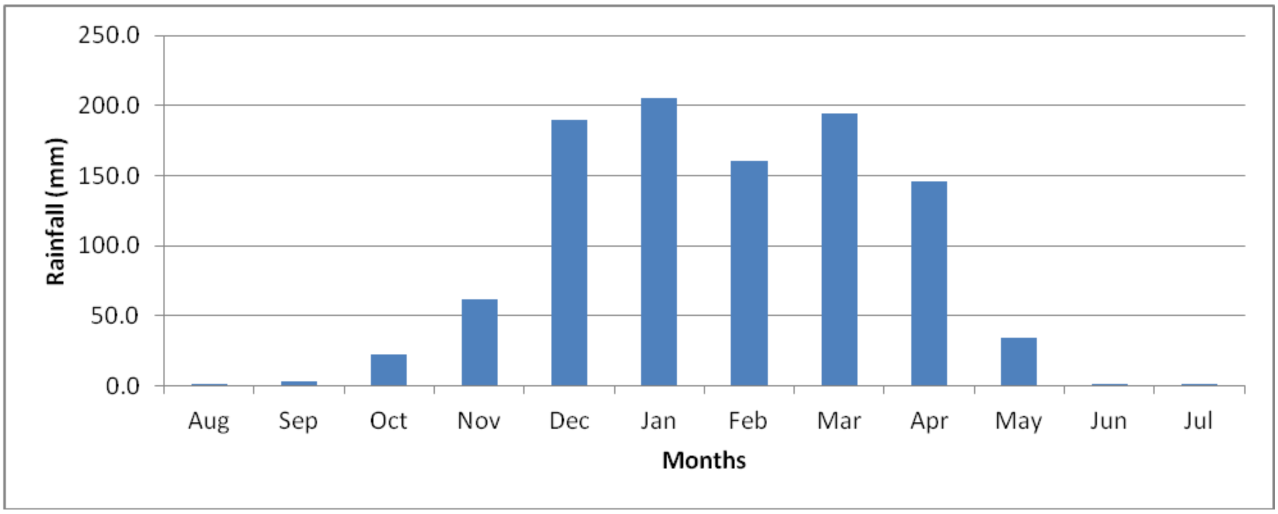


Figure 14: Seasonal variation of rainfall over Uyole station.

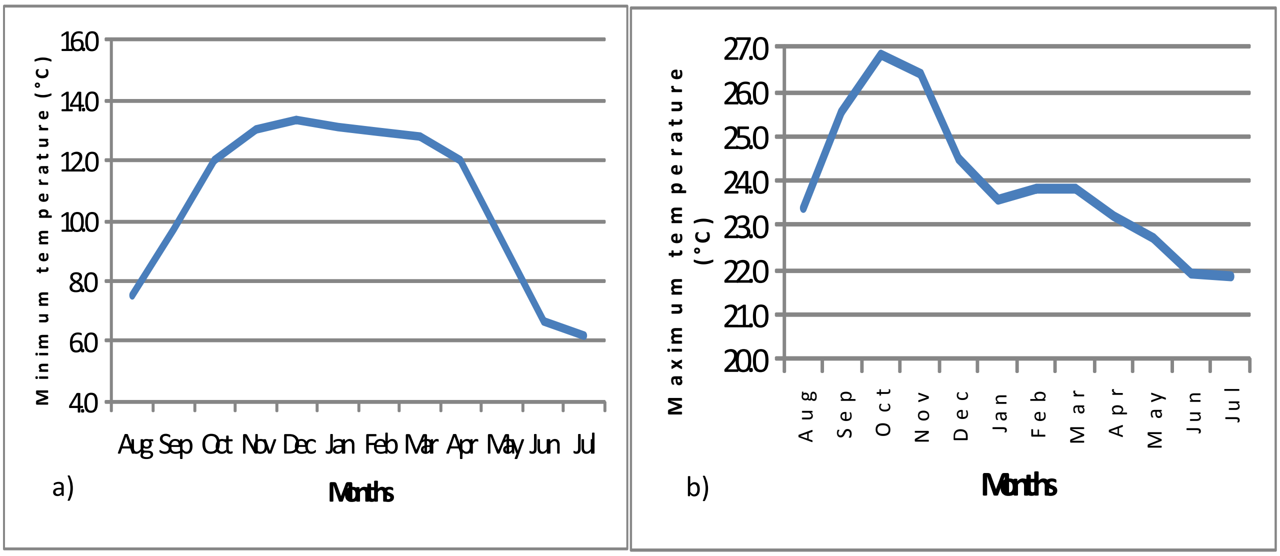


Figure 15: Seasonal variation of a) Minimum and b) Maximum temperature over Uyole station

In figure 14, the study noted that Mbeya region experienced highest amount of rainfall from October to May the following year. Rainfall showed a unimodal patterns with peak over the whole year. Previous studies e.g. Kangalawe, (2009), attributed the decrease in rainfall to the disappearance of short rains that used to be received around September, delayed and fluctuations in the onset of heavy rains. In Figure 15, both the maximum and minimum temperatures showed a single peak over Uyole meteorological station. The minimum temperature observed to be highest between October and March with a mean of approximately 13.6 $^{O}$C as shown in figure (15). However, the maximum temperatures showed a maximum of approximately 26.7 $^{O}$C in October and thereafter, a gradual decreased as the season progressed.

According to studies by INC (2003) and TMA (2005), the mean temperatures will increase throughout the country particularly during the cool months by 3.5°C while annual temperatures will increase between 2.1° C in Mbeya region. Moreover, Rowhani et al. (2011) concluded that in Tanzania by 2050, projected seasonal temperature increases of 2°C may reduce average maize yields by 8.8%.

### 4.3 Effects of climate variables on Maize production

Based on correlation analysis, the relatinship between climate variables and maize production were evaluated Seasonaly and from different Phenological phase, that means ( Sowing to Emergence), (Emergence to Flowering) and (Flowering to Maturity) phase. The results from season were presented in table 3.

**Table 3: Correlation analysis of a Season between climate variable and maize yield**

| Station | Climate Variable | Maize Yield | Test statistic | | Remarks |
|---|---|---|---|---|---|
| | | | t computed | t tabulated | |
| UYOLE | Rainfall | 0.1125 | 0.4901 | 1.984 | Not Significant |
| | TMIN | 0.3673 | 1.5953 | 1.984 | Not Significant |
| | TMAX | -0.3418 | -1.4851 | 1.984 | Not Significant |

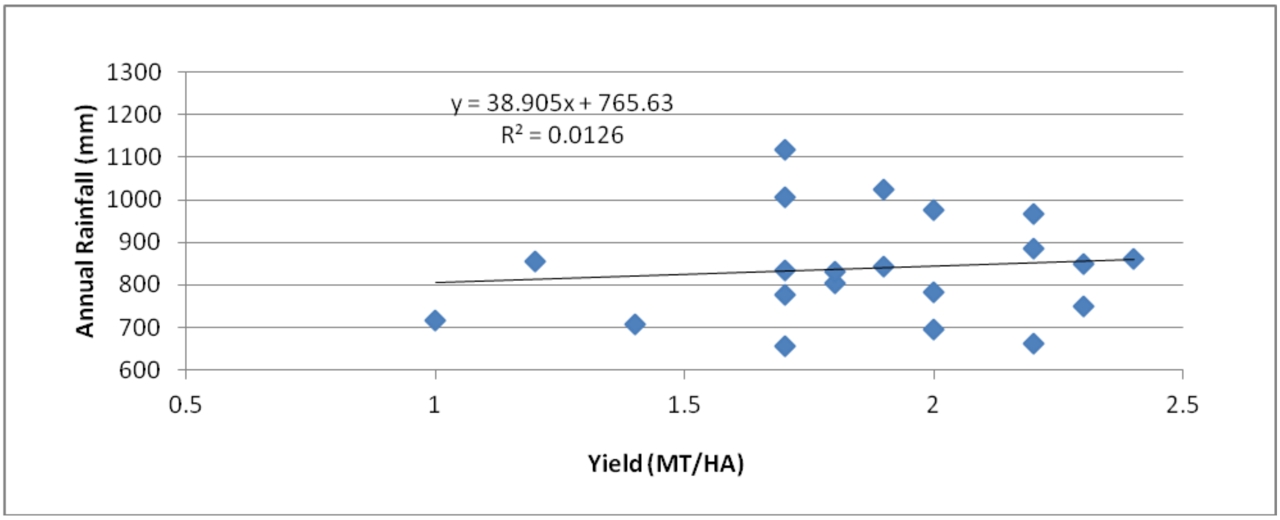


Figure 16: A graph of Correlation between annual rainfall and maize yield over Uyole

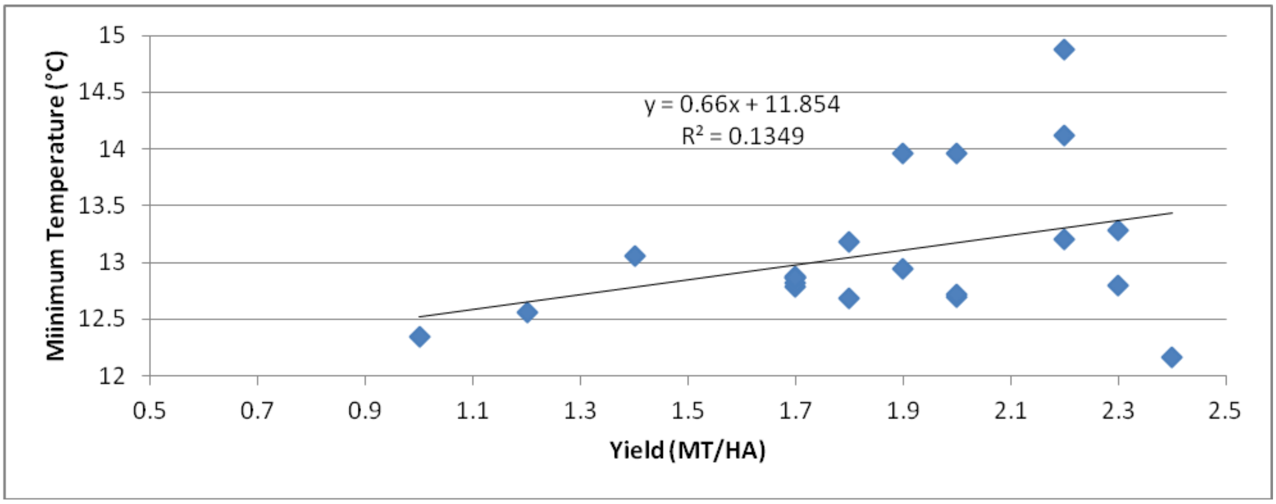


Figure 17: A graph of Correlation between Minimum temperature and maize yield over Uyole

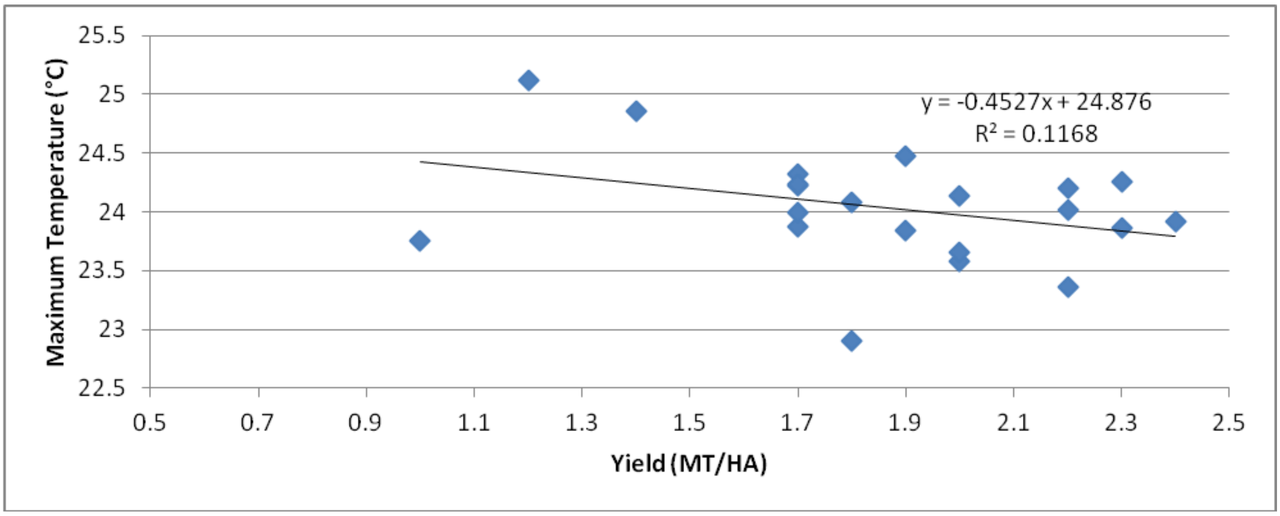


Figure 18: A graph of Correlation between Maximum temperature and maize yield over Uyole.

### 4.3.1 Results from Correlation analysis of a Season between climate variable and maize yields

Correlation analysis indicated that there were positive correlation between rainfall, mean minimum temperature and maize yield over Uyole. But maximum temperature showed a negative relationship. However, all parameters showed smallest individual degree association as indicated by the a small range of $R^2$ which ranged from 0% to 13%. This could be attributed to the fact that all meteorological parameters contribute collectively to maize yield on long term basis.

The test statistic was then used to test the significance of the correlation coefficient at at 95%. It was noted total rainfall, mean minimum and maximum temperature over the study were not significant. This may be because those Climatic parameters used such as Rainfall, mean minimum and maximum temperatures were not the limiting factors as argued by Croon *et al.* (1984), that inadequate weeding is considered the main factor limiting maize yields.

## 4.4 Correlation analysis based on Phenological phase:

**Table 4:** Result of Correlation analysis between climate variables and maize yields from (Sowing to Emergence phase) [DEC and JAN]

| Station | Climate Variable | Maize Yield | Test statistic | | Remarks |
|---|---|---|---|---|---|
| | | | t computed | t tabulated | |
| UYOLE | Rainfall | 0.177861 | 0.787839 | 2.021 | Not significant |
| | T MIN | 0.373318 | 1.75407 | 2.021 | Not significant |
| | T MAX | -0.14669 | -0.64641 | 2.021 | Not significant |

**Table 5**: Result of Correlation analysis between climate variables and maize yields from (Emergence to Flowering phase) [JAN and FEB]

| Station | Climate Variable | Maize Yield | Test statistic | | Remarks |
|---|---|---|---|---|---|
| | | | t computed | t tabulated | |
| UYOLE | Rainfall | -0.05056 | -0.22068 | 2.021 | Not significant |
| | T MIN | 0.360005 | 1.682003 | 2.021 | Not significant |
| | T MAX | -0.35229 | -1.64077 | 2.021 | Not significant |

**Table 6:** Result of Correlation analysis between climate variables and maize yields from (Flowering and Maturity phase) [FEB, MAR and APR]

| Station | Climate Variable | Maize Yield | Test statistic | | Remarks |
|---|---|---|---|---|---|
| | | | t computed | t tabulated | |
| UYOLE | Rainfall | -0.03602 | -0.15711 | 2.000 | Not significant |
| | T MIN | 0.325942 | 1.502816 | 2.000 | Not significant |
| | T MAX | -0.27938 | -1.26828 | 2.000 | Not significant |

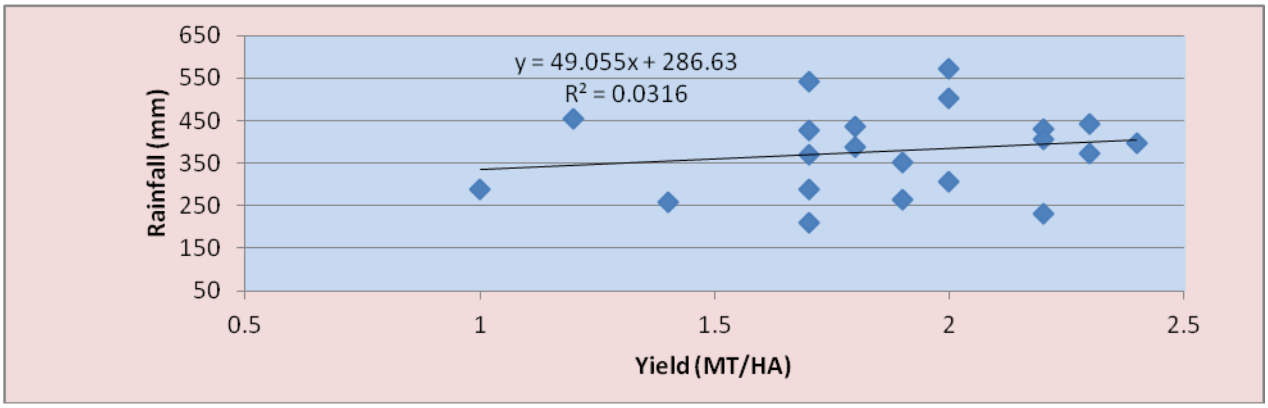


Figure 19: A graph of Correlation between annual rainfall and maize yields from (Sowing to Emergence) phase.

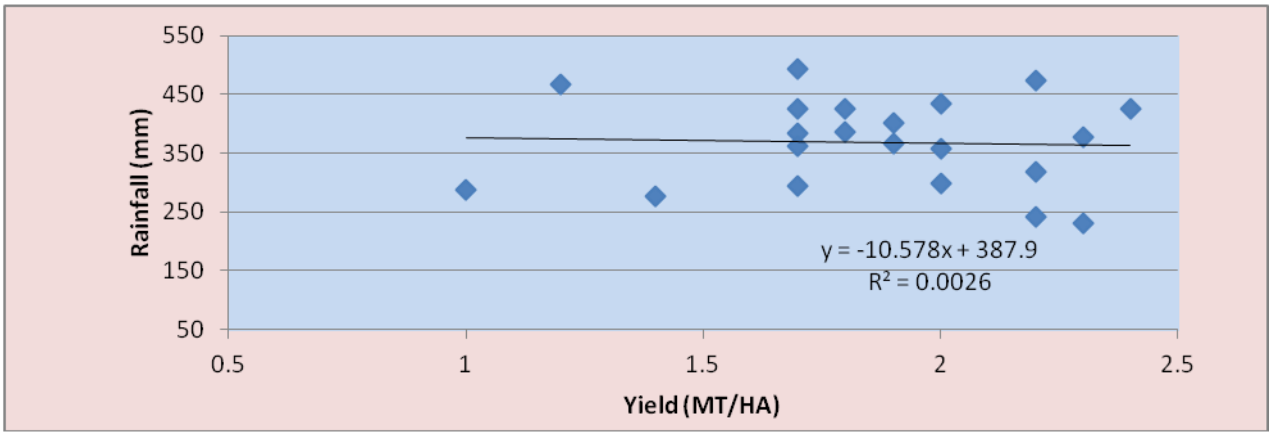


Figure 20: A graph of Correlation between annual rainfall and maize yields from (Emergence to Flowering) phase.

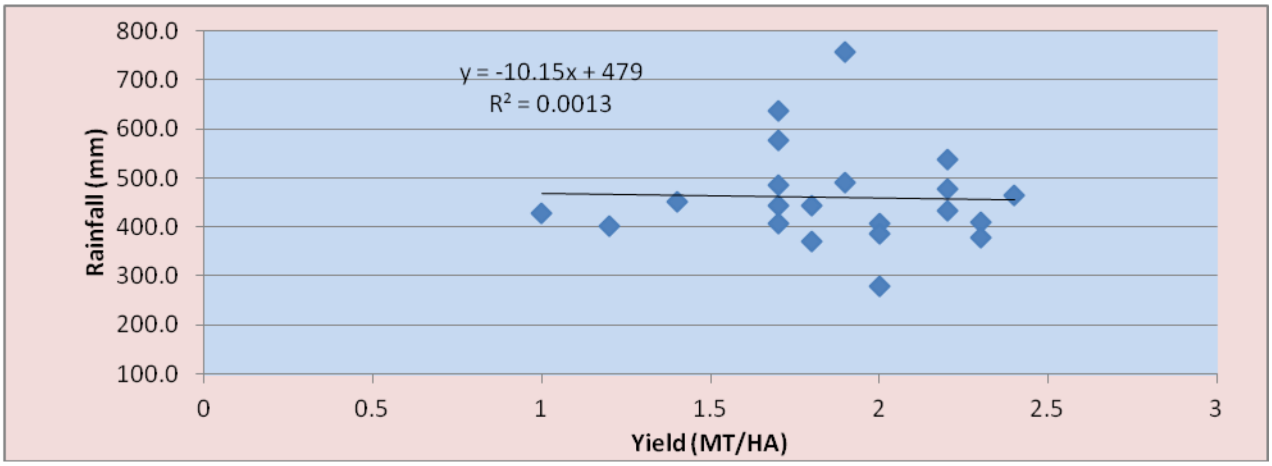


Figure 21: A graph of Correlation between annual rainfall and maize yields from (Flowering to Maturity) phase.

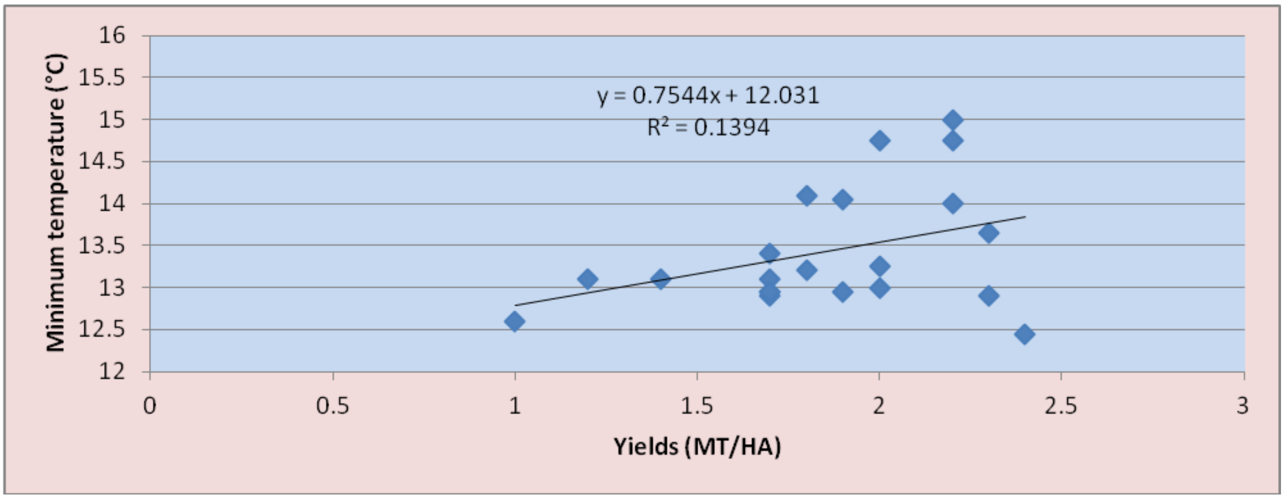


Figure 22: A graph of Correlation between minimum temperature and maize yields from (Sowing to Emergence) phase.

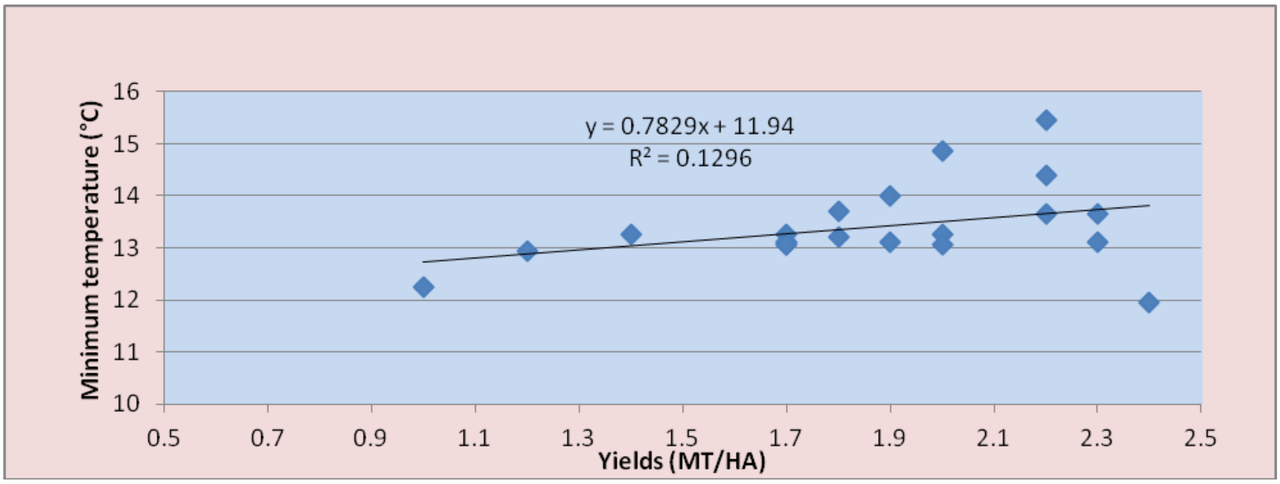


Figure 23: A graph of Correlation between minimum temperature and maize yields from (Emergence to Flowering) phase.

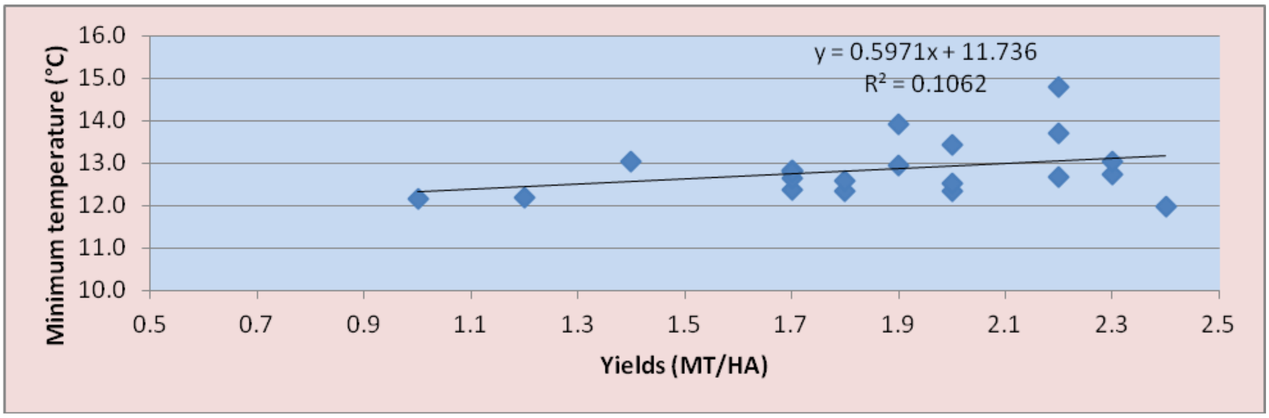


Figure 24: A graph of Correlation between minimum temperature and maize yields from (Flowering to Maturity) phase.

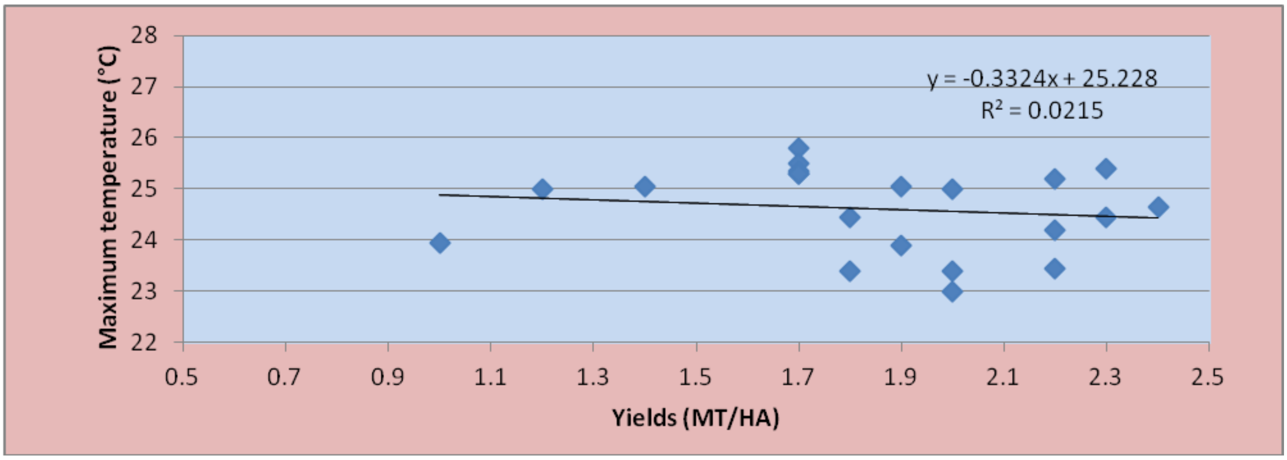


Figure 25: A graph of Correlation between Maximum temperature and maize yields from (Sowing to Emergeence) phase.

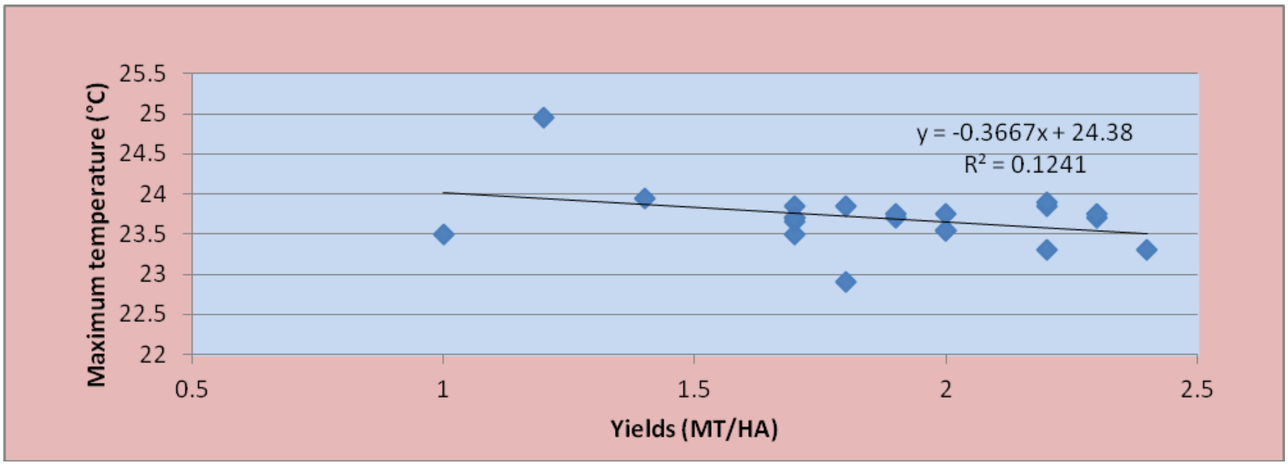


Figure 26: A graph of Correlation between Maximum temperature and maize yields from (Emergence to Flowering) phase.

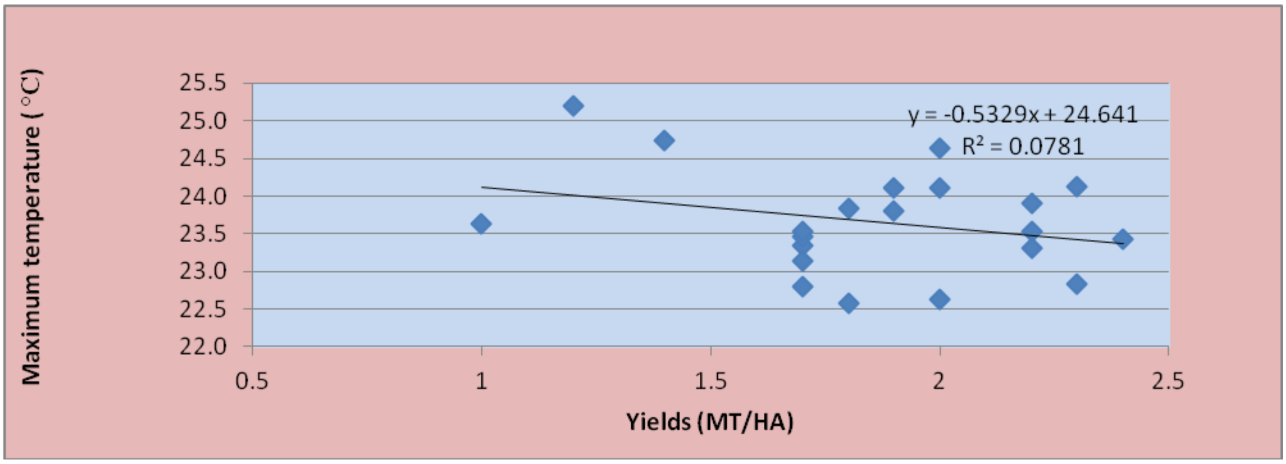


Figure 27: A graph of Correlation between Maximum temperature and maize yields from (Flowering to Maturity) phase.

### 4.4.1 Results from Correlation analysis based on Phenological phase

Correlation analysis indicated a positive correlation between rainfall and maize yields during the first phase, that means between Sowing to Emergence phase and showed negative correlation in the remaining phase. While maximum temperature showed a negative relationship in all phases. However, all parameters showed smallest individual degree association as indicated by a small range of $R^2$ which ranged from 0% to 13%. This could be attributed to the fact that all meteorological parameters contribute collectively to maize yield on seasonal term basis.

The test statistic was then used to test the significance of the correlation coefficient at at 95%. It was noted that the climatic variables used in this study were not significant for the whole phenological stages. This may be because those Climatic parameters used such as Rainfall, mean minimum and maximum temperatures were not the limiting factors. Also due to the fact that the assumption made for the relationship between climatic parameters and maize yields were linear while not linear one, thus why the prediction equation for the prediction of maize yields was not developed.

## Chapter Five

# 5 Summary of the Study, Conclusion and Recommendations

This chapter attempt to provide summary of the results that were derived from various analysis in the study. The conclusion drawn from these results and discussion in chapter 4 are also presented and finally some recommendations for future extensions of this work are highlighted.

## 5.1 Summary of the Study

This study was designed to assess the effect of climate variability on maize production in Mbeya region. Mbeya Region is located on the south-west of Tanzania mainland, commonly known as Southern highland. It boarders with four Regions namely; Rukwa, Tabora, Iringa and Ruvuma.

The focus of the study was over the Mbeya region with special emphasis on Uyole station due to readily available data. The period of study was April to July 2013.

The data used in the study include Annual rainfall; mean minimum and maximum temperatures which obtained from Tanzania Meteorological Agency (TMA). And the data for maize yields obtained from Ministry of Agriculture Food Security and Cooperative in Tanzania.

Methods used in the study include Data quality control for testing the consistency of the data, Estimation of Missing data, Time series analysis and Correlation analysis to measures the relationship between Climatic variables and maize yields.

Time series analysis indicated that that temperature has significantly increased over years and that rainfall has significantly reduced. Increases in temperature could shorten the length of the growing season with temperature variation expected to have significant impacts on the agro ecological zones.

Correlation analysis resulted positive correlation between rainfall and minimum temperature with the maize yields but showed negative correlation for maximum temperature on a season.

Also correlation analysis from different phonological phase indicated the positive correlation for rainfall in the first phase and showed negative correlation in the remaining phase. While maximum temperature showed a negative relationship in all phases.

Regression analysis was not performed this was due to the fact that Correlation analysis from the season and from those phenological phase were not significant to all climatic variables used in this study.

## 5.2 Conclusions

Based on the results, it can be concluded that temperature has significantly increased over years and that rainfall has significantly reduced. Increases in temperature could shorten the length of the growing season with temperature variation expected to have significant impacts on the agro ecological zones. Also the reduction in rainfall and increase in the minimum and maximum temperatures might results in encourage pollen viability and promotion of vegetative growth. The recent study has shown that Maize was a warm weather crop and was not grown in areas where the mean daily temperature was less than 19 ºC or where the mean of the summer months was less than 23 ºC. Although the minimum temperature for germination was 10 ºC, germination will be faster and less variable at soil temperatures of 16 to 18 ºC. At 20 ºC, maize should emerge within five to six days. The critical temperature detrimentally affecting yield was approximately 32 ºC (Plessis, 2003).

## 5.3 Recommendations

Future studies on the effects of climate variability on maize production should consider both the intra and inter seasonal variations of climate variables and phonological stages of maize crop. This will enable determination of individual contribution of climate variables to maize production process. More parameters should be used to develop a regression model to predict maize production such as wind speed and direction, evapo-transpiration and radiation. This could increase reliability of the model. Because from the assumption made under this study for the relationship between climatic parameters and maize yields were linear while not linear one and the modal was not developed, thus it was recommended that other methods should be considered so that to develop the precise and accurate modal to predict maize yields.

## 6.0 Acknowledgement

I begin by thanking Allah for every blessing that he has bestowed upon us and I send blessings to our beloved Prophet Swallawaahu Alyhi Wasallam (SAW).

Second, I would like to thank my Employer Tanzania Meteorological Agency (TMA), for granting me study leave and providing financial assistance during the entire period of study. I further extend my profound appreciation to the Ministry of Agriculture Food security and Cooperatives, Tanzania for providing me Maize Productions and Yields data and information.

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Finally, I extend my sincere thanks to my Wife Mwanaisha H.Pandu and my parents Jecha H. Jecha and Jina U.Makame and my entire relatives for being patient during my absent.

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