IMPACT OF CLIMATE VARIABILITY ON MAIZE PRODUCTION: IN SIHA DISTRICT, TANZANIA

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CERTIFICATION

The undersigned certifies that I have read and hereby recommends for acceptance by The Open University of Tanzania, a dissertation entitled *"Impact of Climate Variability on Maize Production: In Siha District*, *Tanzania"*, in partial fulfilment of the requirement for the degree of Master of arts in natural resources assessment and management of the Open University of Tanzania.

Dr. Reguli B.Mushy

(Supervisor)

Date

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DECLARATION

I, William Raymond Nzaro, hereby declare that this dissertation is my own original work towards the **Master of Arts in Natural Resources Assessment and Management** and that, to the best of my knowledge, it contains neither material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where the acknowledgement has been made in the next.

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Signature

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Date

DEDICATION

This research is mainly dedicated to my Father Eliefika (Raymond) Nzaro Mjema, my beloved mother Elizabeth William Sekajingo together with my affectionate wife Maria Gaspar and my dearest daughter Jaina W. Nzaro for their diligent hold-up and through their daily prayers for me. It is their support which made me accomplish this research work.

ABSTRACT

Climate variability has a large effect on the agriculture sector and, consequently on maize production for residents of Siha District and other regions of Tanzania. A descriptive concurrent mixed method to gather data relating to the effects of climate variability on maize production was used. For primary data a sample of 92 respondents was selected through probability and non probability techniques, 92 respondents filled the questionnaire which was validated through an expert in the Meteorological station and agriculture sector. For time series analysis a sample of 30 years (1988-2018) was selected. The reliability test yielded the Cronbach's Alpha of above 0.7 meaning the questionnaire was reliable for data collection. Data were analyzed through descriptive and inferential statistics to determine the impact of climate variability on maize production in Siha District in Tanzania. The study further examined the impact of future climate variability scenarios to see how maize production in the sub humid and semi-arid areas will respond to climate variability by assessing the effects of climate variability on maize production. Based on the results, it can be concluded that temperature has significantly increased over the 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. Climate variability effects on maize production resulted to severe and prolonged droughts, floods and changes to growing seasons that have significant effects for soil productivity, water supply, food security and in turn human welfare as well as harmful on land resources and, otherwise, can lead to irreversible impacts on biological diversity. Just as agricultural productivity gains have always been closely linked to poverty reduction, productivity decline in tropical and subtropical agriculture that will result from climate change can be expected to increase the depth and severity of poverty. To mitigate climate variability and provide effective adaptation measures, it is important for the government, research units, and private sectors to invest resources in training farmers and supporting them against further adverse climatic conditions.

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URT	United Republic of Tanzania.
GDP	Gross Domestic Product
TMA	Tanzania Meteorological Agency
KIA	Kilimanjaro International Airport
IPCC	The International Panel on Climate Change
UNFCCC	United Nations Framework on Climate Change
FAO	Food and Agriculture Organisation
UNDP	United Nations Development Programme
AUC	Area Under Cultivation
T	Temperature
FPI	Food Price Index
CAN	Calcium Ammonium Nitrate
SA	Sulphate of Ammonia
NPK	Nitrogen, Phosphorus and Potassium
Ha	Hectare
KG	Kilogram
FSIT	Food Situation Assessment Team
MPD	Maize Production
RFA	Rainfall

CHAPTER ONE

INTRODUCTION

1.0 Overview

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 pro- vides 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). Changes in climate have already decreased crop yields in several regions and, for example, are estimated to have reduced global maize production by 12 Mt a year between 1981 and 2002 (Lobell and Field, 2007).

It has been suggested that a larger percentage of the African population will enter poverty as short-term changes in climate will increase the stress on food production (Ahmed et al., 2009a). Sub- Saharan Africa (SSA) relies heavily on weather-sensitive agriculture

(Stige *et al.* 2006). Moreover, hunger and poverty prevail in SSA and it is crucial to prioritize investments and policy in this region in order to prevent the destructive impacts of future changes in climate on food production (Lobell *et al.*, 2008; Schlenker and Lobell, 2010).

1.1 Background to the research problem

Tanzania is a vast country; it experiences a diverse climate and hence diverse climate from one area to another. According to studies by INC (2003) and TMA (2005), the mean temperatures tend to increase throughout the country particularly during the cool months by 3.5oC while annual temperatures will increase between 2.1 C in Hai and Siha District. 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%. Despite the importance of maize as the main staple crop in Tanzania, it is currently hampered by a wide range of constraints, such as; enormously variability in rainfall. Change in the seasonal precipitation patterns may affect the total maize production despite the high total annual rainfall.

The contribution of the agricultural sector to the economic growth and the development of Tanzanians have continued to increase. In 2015, the agricultural sector contributed 29% of the GDP, compared to 28.8% in 2014. This was the largest contribution, surpassing all other sectors. (URT, 2016), 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, the 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). Tanzania is a leading country for maize production in East Africa, 45% of Tanzanian land is used for maize cultivation in which 4.5 million of households utilize their land for maize cultivation. **(**Anderson *et al.*, 2015). The contribution of smallholders is 85% of total national cultivation with the rest of the contribution being from community farms, large farms (private and public) (Bill & Melinda Gates Foundation, 2014)**.**

As demonstrated by crop productivity is highly dependent on climate and weather under rain-fed agriculture. Additionally, works carried out on crop-climate relationships around the globe have revealed that there is a considerable relationship between weather and climate on crop yields. In Nigeria, inter-annual rainfall variability has shown to be a major cause of stress in farming and crop production. In Argentina, Podesta *et al.* (2005) demonstrated that climate variability is strongly correlated with yields of maize, sorghum, and soybeans in the Pambas, Southern Argentina, as a result of El Nino Southern Oscillation (ENSO). The interaction between an increase in temperature and precipitation as a result of climate change is likely to result in the loss of arable land due to decreased soil moisture, increased aridity, increased salinity, and groundwater depletion. Overall, crop yields in Africa are projected to fall by 10–20 % to 2050 because of warming and drying, but there are places where yield losses may be much more severe, as well as areas where crop yields may increase. There is a need to determine how changing climate parameters plays a critical role in yields of maize in lower eastern Kenya's ASALs to guide agricultural planning and enhance the adaptive capacity of smallholder farmers.

In this study, we will also report a strong and significant situation of climate variability in the Northern zone which has led to reduced maize production and other crops over the years in the former Hai District (now Siha and Hai Districts). These observed reductions in maize yield are mainly due to increases in temperature and decreases in rainfall amount and distribution during the growing season that affects the development of the crops and their attainment to maturity. The inferred temperature sensitivities were negative for both maize and bean crops in agreement with several previous assessments (Agrawala *et al.*, 2003; Lobell and Field, 2007; Schlenker and Roberts, 2009; Lobell and Gourdji, (2012). The six most widely grown crops in Hai and Siha Districts are maize, common bean, coffee, banana, rice, and sunflower. Production of these crops accounts for over 46 percent of Hai and Siha Districts cropland area and more than 82 percent of food production, grown by more than 80 percent of the small scale farmers/residents whose primary source of livelihood is agriculture (URT, 2001, 2012b).

It is quite remarkable that maize yields in the past few decades have been varying and is closely associated with climate variability. Thus, from all the analysis, it is clear that the variations in rainfall, temperature, and evaporation tend to have a remarkable effect on maize yields in the entire study area over the period 1988–2018 and subsequently astounding impacts on the population.

1.2 Statement of the research problem

In East Africa, climate change and variability have been altering temperatures and distribution of rainfall, which contributes to sea-level rise and increase the frequency and intensity of extreme weather events (Low, 2005; Orindi and Murray, 2005). The intensity of droughts, floods and changes to growing seasons have significant effects for soil productivity, water supply, food security and in turn human welfare as well as harmful on land resources and, otherwise, can lead to irreversible impacts on biological diversity (AIACC, 2006; Yanda *et al.,(*2006). The ecological gradient that ranges from higher rainfall potential to lower rainfall potential where livelihood systems interact across the different zone have been affected hence influencing land management (Majule *et al. (*2004). Some of the extreme weather in Tanzania has been the droughts of 1974, 1983, and 1994, which were followed by abnormal climate conditions of El Nino of 1982 - 83 and 1997 - 98 (Majule *et al.* (2004); Yanda *et al.(*2006).

The expected decline in agricultural productivity will negatively impact the poor, as well as producers and consumers via reduced food production and higher food prices. Just as agricultural productivity gains have always been closely linked to poverty reduction, productivity decline in tropical and subtropical agriculture that will result from climate change can be expected to increase the depth and severity of poverty. This potential income loss can trigger increased vulnerability to poverty and hunger for many households, with particularly negative impacts for women, children, elderly and disabled (FAO, 2008a). 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.

So, farmers in the area are not sure of the output of the maize production in relation to what they have invested – cultivation costs, a situation which sometimes lead to loss of capital. It is this situation that triggered the researcher to undertake the research of establishing the effect of the climate variability on maize production so that farmers are more informed of what they should expect when engaging in maize production.

1.3 Objectives of the study

1.3.1 General Objective

The main objective of this study is to assess the effects of climate variability on Maize production in Kilimanjaro Region, Tanzania

1.3.2 Specific Objectives

i) To examine the influence of temporal variability of rainfall on maize production in Siha District for the last 30 years.

ii) To examine the influence of seasonal variation of temperature on maize production in Siha District for the last 30 years.

iii) To evaluate the marginal effects of temperature and rainfall on maize production in Siha District.

1.4 Research Questions

i) How does temporal variability of rainfall influence maize production in Siha district for the last 30 years?

ii) How is the seasonal variation of temperature influence maize production in Siha district for the last 30 years?

iii) What are the marginal effects of temperature and rainfall on maize production in Siha District?

1.5 Significance of the study

This study is significant as it will assist decision and policy-makers in the agriculture sector in Tanzania to understand challenges related to effects of climate variability on maize production, their implications and ways of bridging the gaps; in order to make evidence-based decisions. The findings of this study will serve as a baseline for other forthcoming studies dealing with climate variability on maize production. The findings are expected to inform the government to take appropriate and effective assessment and mitigation measures for study also sought to propose adaptation options that could be taken up to mitigate the impact sustainable management of the effects of climate variability in Tanzania. This study also acts as a guideline for future researchers who will be interested in similar studies on the effects of climate variability on maize production. Since this research is a necessary qualification for education, upon completion will lead to the award of the degree of Master of Arts in Natural Resources Assessment and Management (MA-NRAM). Other researchers will also benefit from the information generated from this study for further studies.

Finally, this study helps other researchers in various academic institutions to undertake further research in order to add more knowledge to the topic.

1.6. Scope of the study

The study intended to find out the effects of Climate Variability on maize Production. While the study recognizes that Climate Variability has an impact on other crops in terms of production, and as such, this study was limited itself only on maize production in Siha District. The study focused itself only on two villages which are based in Siha district.

1.7 Limitations and Delimitations of the study

The study was limited by time and financial resources and as a result, the researcher was supposed to use alternative means. Since few similar studies have been done especially in institutions of higher learning, there is limited empirical literature on the area of effects of Climate variability on Maize Production change especially in the context of Siha District. Another limitation was that the respondents (farmers) failed to give correct information on the basis of invasion of their privacy. The researcher explained to them that the study is purely for academic purposes and not motivated by any other interests whatsoever.

Despite the study being faced by numbers of limitations such as financial constraints, the researcher tried to balance and minimize the cost through the use of village leaders and some famous people who were given little token so that they helped on meeting the individuals especially those who demanded payments so that they would share information. Sometimes poor cooperation with the respondents was solved by village leaders who took time to discuss with them until they get ready to share with me in their household and then responded well during the interviews.

1.8 Organization of the Dissertation

This dissertation is organized into five chapters. The introduction chapter presents the background of the research problem, the statement of the research problem, research objectives as well as research questions. Significance of the study as well as organization of the dissertation, Literature review is presented in chapter two where different studies were reviewed with a focus on the effects of climate variability on maize production. Chapter three focuses on the methodology of the study. Chapter four presents the findings and discussion of the findings obtained from the field in relation to specific objectives. The last chapter presents the summary, summary of the findings, conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

According to Barley, (1999) a review of literature refers to the process of identifying, reading, evaluating, summarizing and incorporating in your study documents having materials that are related to the problem under investigation. This chapter consists of four parts which are the definitions of key concepts, analytical framework, theoretical literature review, and empirical literature review. The theoretical literature review dealt with the theories used to guide this study while the empirical literature reviews reviewed studies from different parts of the world that are related to the study. The objective behind the review of all these kinds of literature is to expand the knowledge that the researcher already had and to learn new knowledge related to the study at hand.

2.2 Conceptualization of key terms

2.2.1 Climate

The word climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World

Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind (Field *et al*. 2012).

2.2.2 Climate variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, Glossary of terms, 2012).

But also according to IPCC (2007), Climate variability also has been defined as “variations in the mean state and other statistics (such as standard deviation and the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. On the other hand, climate variability is a year to year fluctuation of climate around normal or is the way climate fluctuates yearly above or below a long-term average value (Dinse, 2009).

2.2.3 Temperature

The word, temperature has been defined 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 (Went, 1953).

2.3. Theoretical Literature Review

2.3.1. The Production Function Approach

The production function approach was the pioneering approach in Economics and Econometrics. It was put forward by two economists namely Charles Cobb and Paul Douglas from 1927-1947. The production function has been applied in various areas, including on the impact of climate change on agriculture. The approach is based upon experimental or empirical production functions where environmental variables such as precipitation or temperature are inputs. These environmental variables in the production function are varied so as to estimate the impacts of climate change on yields. These changes in yields are then incorporated in economic models so as to predicate the changes in welfare as a result of climate change (Mendelsohn *et al*. 1994).

The production function approach has the advantage of providing estimates of the impact of climate that are free of bias as a result of the determinants of agricultural production that are beyond a farmer's control such as soil quality (Deschenes and Greenstone, 2006). In addition, the approach provides better predictions of the impact of climate change on agricultural yields because of its use of controlled experiments (Mendelsohn *et al.* 1994; Deschenes and Greenstone, 2006).

Despite this, the approach suffers from some limitations. First, the approach doesn't incorporate adaptation measures adopted by farmers in the face of climate change. This is unlikely since farmers will respond to the changing climate conditions. They may introduce new crops or replace crops with livestock. The lack of incorporation of adaptation measures 12 results in an overestimation of damages as a result of climate change (Mendelsohn *et al*. 1994). Secondly, the approach is very expensive because of the controlled experimentation required (Deressa, 2007). This may explain why the approach has been used in a few sites around the world and for a few crops mainly grains. Hence, the approach may be of little value for generalizing results.

2.3.2. The Ricardian Approach

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

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

However, the approach suffers from some limitations. One limitation is that the Ricardian approach fails to incorporate the transition costs a farmer may bear as a result of moving from one adaptation option to another as a result of climate change. For example, if a farmer introduces a new crop because of changing weather conditions, the approach assumes the costs associated with the new crop will be borne by the farmer. However, if that new crop fails and the farmer introduces another new crop, the approach fails to capture costs associated with moving to other new crops.

Another limitation is that the approach fails to measure the effect of variables that don't vary across space. For example, the effect of carbon dioxide levels which are generally the same across the world (Kurukulasuriya and Mendelsohn, 2008). Another weakness of the approach is that it affected by aggregation bias. However, this weakness also affects other hedonic models and is not restricted to the Ricardian model only (Fezzi *et al.*, 2010). Finally, the approach doesn't fully control for the impact of important variables other than climatic factors that could explain the variation in land values or farm revenues (Kurukulasuriya and Rosenthal, 2003).

2.4 Empirical Literature

2.4.1 Climate variability and its effects on maize production

Climate change and variability present new development challenges, particularly in Sub-Saharan African countries where the majority of the population depend on climate-sensitive activities such as agricultural production (IPCC, 2007). This has rendered these countries to be more vulnerable to climate change and variability (Kurukulasuriya and Mendelsohn, 2008). In these countries, vulnerability to climate change impacts is underscored by the severe droughts experienced in the Sahel in 2012 and the Horn of Africa in 2011(Sarr, 2012). In Tanzania for example, climate variability affects nearly 80% of the population who directly or indirectly depend on rain-fed agriculture (Thornton, 2011; WB, 2011). For a significant period of time now the country is experiencing decreasing and increasing trends of rainfall and temperature respectively as well as persistent droughts and floods in many parts (Shemsanga, 2010). These climatic trends have created new burdens for those already poor and vulnerable (Brooks *et al*., 2009). For the most vulnerable groups, exposures to new climatic variability risks coupled with crop failures, food and income insecurity, malnutrition and ill health are 'the latest in a series of pressures and stresses they are facing' (Vrieling *et al*., 2013).

Also, the study was done by Oseni *et al. (*2011) on the effect of climate change on maize (*zea mays*) production and food security in Swaziland attempted to investigate the impact of climate change on rain-dependent maize production and household food security in Swaziland. Maize production on the Swazi Nation Land (SNL) depends solely on natural precipitation and rainfall variability affects its production. The results indicate that reduction in both mean annual and planting season precipitation has negative impacts on maize production and which may pose a serious threat to household food security since maize is the staple food of most Swazi people.

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 fact that climate is changing and mitigation efforts to reduce the sources or enhance the sinks of greenhouse gases will take time as it involves the diverse global community, regional and country initiatives to adapt to changes are imperative. This is of great concern in developing countries where vulnerability to climate change effects is high due to the low capacity to absorb climate change shocks. Adaptation helps farmers achieve their food, income and livelihood security in the face of changing climatic conditions, extreme weather conditions such as droughts and floods (IISD, 2007; De Wit and Stankiewicz, 2006; Kandlinkar and Risbey, 2000). It is believed that small scale farmers can reduce potential damage by making tactical responses to these changes (Maddison, 2006; Mano *et al*. (2003). However, this will be difficult if climate change effects and compatibility of adaptation mechanisms are taken holistically. Understanding the effects at the microclimatic difference and the compatibility adaptation mechanisms used by small scale farmers at these levels is therefore deemed important for finding credible ways to help farmers produce enough for food and income for other household needs.

Kahimba *et al*. (2015) and Philipo *et al*. (2015) both conducted a review of literature to identify knowledge gaps in climate change in relation to food security research. The review recommended more research to be geared towards combining mitigation and adaptation strategies against the impacts of climate change, reduction of greenhouse gas emissions, and increase of food security. So in reference to these recommendations, the current study is one response as it deals with climate change in Siha District and it affects maize crop productions, thereby giving specific recommendations.

For example, Mkonda and He (2018) have conducted a recent study with the aim of measuring climate variability and how it affects crop yields synergies in Tanzania's semi-arid agro-ecological zone. The outcome indicated that there is a dramatic decrease in rainfall, an increase in temperature. These findings have an impact on implementing useful adaptation measures, especially to vulnerable communities. Therefore, in reference to this study, the on-going study is going to explore a different region namely Siha District, Kilimanjaro to determine if climate variability has affected maize production.

On the same vein, Nyangas *et al*. (2016) conducted a study with the aim to measure perceptions on resilience to climate change variability among farmers in Meatu and Iramba Districts, Tanzania. The study indicated that over 73% of household heads were resilient; this was determined by household income, marital status, and land ownership. The study recommended more training provision especially on engaging in non-farm economic activities. The recommendation appears to be significant and useful, but perhaps may not be useful to a different agro-ecological zone where Siha, District in Kilimanjaro is located.

Other studies have been done either in isles or coastal regions (Bakari, 2015 and Kashaigili *et al*. 2014). For example, Bakari (2015) conducted a study in three Shehi as within Micheweni District, Pemba. The study aimed to identify and assess climate change impacts to small scale farmers. The results indicated an annual decrease in crop production in the past 10 years, with pests and diseases, uneven distributed low rainfall and extended drought periods. Crop rotation, use of improved seeds and new crop varieties, fertilizer application, irrigation, mixed cropping and adjusting sowing dates were some of the adaptation strategies. Sea water rise and intrusion constrained paddy farms production where fish and salt farming contributed to environmental degradation in farming areas. Whereas this study has significant impact in in the isles and probably in the coastal regions, it may perhaps not bear a similar impact in in northern highlands of Tanzania where Siha District is located, hence the need for the study.

Another study was done in the western part of Tanzania. For instance, Msuya (2010) conducted a study among smallholder farmers in the highland zone of Kigoma District. The aim of the study was to determine climate variability in coffee production. The data collected spanned 30 years. It involved 120 respondents in 5 villages. The correlation between trends was insignificant at 5% probability level. This indicates that coffee production was probably affected by other factors. So in reference to this study, the ongoing study is similar because both are dealing with one crop, they have data which spans 30 years. However the difference is location, the former was conducted in Kigoma, but the current was done in Siha District, Kilimanjaro. So the current study is intended to yield different data because of the nature of location and type of crops investigated.

Yet others were done in the southern part like Morogoro, in this area, Kabele (2011) conducted a study in Mvomero District with the aim of assessing climate change adaptations techniques among small holder farmers. The results indicated that the adoption of climate change adaptation measures varied by household characteristics, knowledge and climate change adaptation practice. This was due to low knowledge, inadequate information and lack of financial capital. The study recommended in order to improve adaptability to climate change impacts, there is a need for more awareness among farmers is through training, seminars and information transfer through mass media. This study is very useful for surrounding areas of Mvomero District, however, similar recommendations may not be useful to a different agro-ecological zone where Siha District in Kilimanjaro is located, hence the rationale for the current study.

Another similar study was done in Morogoro District by Joseph (2015). The aim of the study was to determine the effectiveness of climate change. The findings indicated that farmers are already adapting to climate changes; also most farmers lacked agricultural education to aid them in interventions; the study concluded in need for more agricultural education and financial support to smallholder famers. Therefore, in reference to this study, the on-going study focuses on how climate change affects maize crop production in Siha, District. The main difference between the two studies is location and type of crops dealt with. The former was not specific to a particular crop, while the later focuses on maize production, thereby being able to give specific recommendations.

A trend of studies in the last 10 years shows the scarcity for research in North-east Region. Nevertheless, Ajuaye (2010) conducted a study in 12 villages in Moshi Rural, Hai and Rombo Districts, Kilimanjaro Region. The study aimed at assessing adaptation mechanisms to climate change in the region. The results confirm that farmers are quite aware of climate change and adaptation options. Seasonal drought, temperature change and the outbreak of diseases in plants and animals were the most perceived consequences of climate change. The adaptation strategies used included change of farm management practices and adoption off-farm employment. Timing of farm operations, water harvesting, mulching, change of crop varieties, irrigation and agro-forestry were the major farm-copping strategies. These strategies were observed to have a positive and significant influence on maize and banana yield. Also, the study found out that household assets; household size; education level; extension services; owned land size and access to irrigation are the major factors that influence the adoption of adaptation strategies. The adaptation strategies used included change of farm management practices and adoption off-farm employment. Timing of farm operations, water harvesting, mulching, change of crop varieties, irrigation and agro-forestry were the major farm-copping strategies. These strategies were observed to have a positive and significant influence on maize and banana yield. Also, the study found out that household assets; household size; education level; extension services; owned land size and access to irrigation are the major factors that influence the adoption of adaptation strategies. This study is meaningful to trends of climate variability and how it affects adaptations, however, the on-going study will venture into specific adaptation on maize crop.

2.4.2 Maize production technology recommendations

As indicated, most maize growing areas in Tanzania are divided into three agro-ecological zones: the low altitude zone (less than 900 masl); the medium-altitude zone (900-1,500 masl); and the high altitude zone (above 1,500 masl). Maize production recommendations were developed to fit the agro-ecological zones. (Nkonya *et al*., 1998)

2.4.2.1 Varieties

The choice of maize variety is determined by the farmer's objective, the length of growing season, the elevation, and the amount of rainfall. Also, we have recommended varieties for the various ecological zones in Tanzania. (Nkonya *et al*., 1998)

2.4.2.2 Planting time, method, and spacing

Generally, early sowing is the most important single factor for increased grain yield (Goodbody 1990). Lower yields and increased pests and disease attacks occur with late sowing. Varieties susceptible to maize streak virus disease suffer more when sown late. The total length of the growing season and the number of days to silking of varieties influencing the decision on when and what variety to grow. If the rains come late, farmers are advised to plant early maturing varieties even in areas that are suitable for full-season varieties.

In most areas of the Northern Zone maize is normally sown between mid-January and mid-March. In isolated pockets that have bimodal rainfall: Rombo, Mwanga, and Same districts in Kilimanjaro region-farmers also sow their maize in October. (Nkonya *et al*. 1998)

2.4.2.3 Fertilizer type, time, and method

To provide nitrogen one can use either urea, calcium ammonium nitrate (CAN), or sulfate of ammonia (SA). Nitrogen application may be split, with 30-50% of the total requirement applied at planting. The remaining N should be applied when maize is about a meter high. Phosphorus (P2O5) is necessary to promote root growth, strong stems, and good grain.

Fertilizer is normally placed 5 cm below the depth of the seed and about 5 cm to the side. This is accomplished by digging a single hole beside each seed and placing fertilizer in the hole and covering it with soil. Alternatively, a continuous furrow can be made along the length of the planting row. Fertilizer is then placed in the furrow and covered with soil. The seed is then planted on top of this soil and covered properly. (Nkonya *et al*. 1998)

2.4.2.4 Weeding time, frequency, and method

Weed control in maize is important to reduce competition for water, soil nutrients, and light. Research results have consistently shown that late and poor weeding can result in yield reductions of 30% to 70% (Matowo and Mgema 1990a). Generally, two hand-weeding should suffice at all elevations. However, durations between the first and second weeding vary between locations. (Nkonya *et al*. 1998)

2.4.3 Climatic requirements

Maize is a warm-weather crop and is not grown in areas where the mean daily temperature is less than 19 ºC or where the mean of the summer months is less than 23 ºC. Although the minimum temperature for germination is 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 is approximately 32 ºC. Frost can damage maize at all growth stages and a frost-free period 120 to 140 days is required to prevent damage. While the growth point is below the soil surface, new leaves will form and frost damage will not be too serious. Leaves of mature plants are easily damaged by frost and grain filling can be adversely affected. (Nkonya *et al*. 1998)

2.4.3.1 Water

Approximately 10 to 16 kg of grain are produced for every millimeter of water used. A yield of 3 152 kg/ha requires between 350 and 450 mm of rain per annum. At maturity, each plant will have used 250 L of water in the absence of moisture stress (Nkonya *et al*., 1998)

2.4.3.2 Production potential

Several methods can be used to determine yield potential, each with its own limitations. One of the most reliable methods is long-term yield data collected by each individual producer, as this reflects an inherent yield of the specific environment, as well as the effect of agronomic practices such as fertilization, soil cultivation, and plant population and managerial abilities of the producer (Nkonya *et al*. 1998).

2.4.4 Temporal variability of rainfall and temperature

There has been a temporal variability of rainfall and temperature for a long period of time. Therefore, the historical data shows that there has been a decline in rainfall amounts, onset, and sensations of rainfall almost within 30 years hence they experienced droughts due to inadequate rainfall.

A higher amount of rainfall in maize is received in March to May period corresponding to the long rains season. The historical data shows that during this period rainfall ranges from 223 mm to 656 mm with an average of 465 mm. Lower rainfall is received in January to February period corresponding to relatively dry season. During this period rainfall ranges between a minimum of 29 mm and a maximum of 318 mm with an average of 117 mm.

In terms of temperature, the historical data shows that the mean temperature is relatively high in maize growing areas for all periods. Higher mean temperatures are observed in

June to September period with an average mean temperature of 19.390C in maize. The lower mean temperature is observed in March to May period with an average of 17.750C.

The analysis of historical data from TMA showed a statistically significant increase in maximum and minimum temperature at p-value = 0.0072 in Kilimanjaro Airport Station.

2.4.5 Seasonal variation of maize production

Seasonal variations have been fluctuating since time immemorial which leads to changes in onset and cessation of rain season over the past years.
Maize production in Siha has been on steady decline due to erratic rainfall variability and the area planted maize has also been reduced to adapt to the anticipated drought period. The risk associated with climate variability of maize production, in general, depends mainly on the growth stage of the maize crop when the weather aberration occurs. Statistics on maize production and productivity from (Table 4.6), shows that Siha has not been able to meet its maize requirements as the observed declines in production and yield coincide with the occurrence of low/or erratic rainfall.

2.4.6 Impacts of temperature and rainfall variability on maize production

The effects of rainfall and temperature on maize production which are the results of climate variability in Siha include shifting in agro-ecological zones, prolonged dry episodes, reduced crop production, unpredictability in rainfall, uncertainty in cropping patterns, increased weed competition with crops for (moisture, nutrients and light) and ecological changes for pests and diseases.

As indicated in the results, climate variability has a large effect on the agriculture sector and consequently on the food available for residents of Siha District and other parts of the country. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. During the last 120 years, annual precipitation on Mount Kilimanjaro (including Siha District previous known as Hai District) has decreased by 600 - 1200 mm. Both these climatic variability do not only cause the glaciers on the mountain to retreat but also intensity and frequency of droughts are likely to increase, resulting in a potentially much greater impact on the overall livestock and crop production in the neighborhood of Kilimanjaro ecosystem (Munishi *et al,* 2006).

2.6 Conceptual Framework

The conceptual framework is a model that shows the relationship between the variables graphically or diagrammatically (Orodha, 2004). The model consisted of two variables independent variables that are the rainfall amount, temperature, soil productivity condition, and land ownership and dependent variable that is food security(maize output in yield) (Figure 2.1).

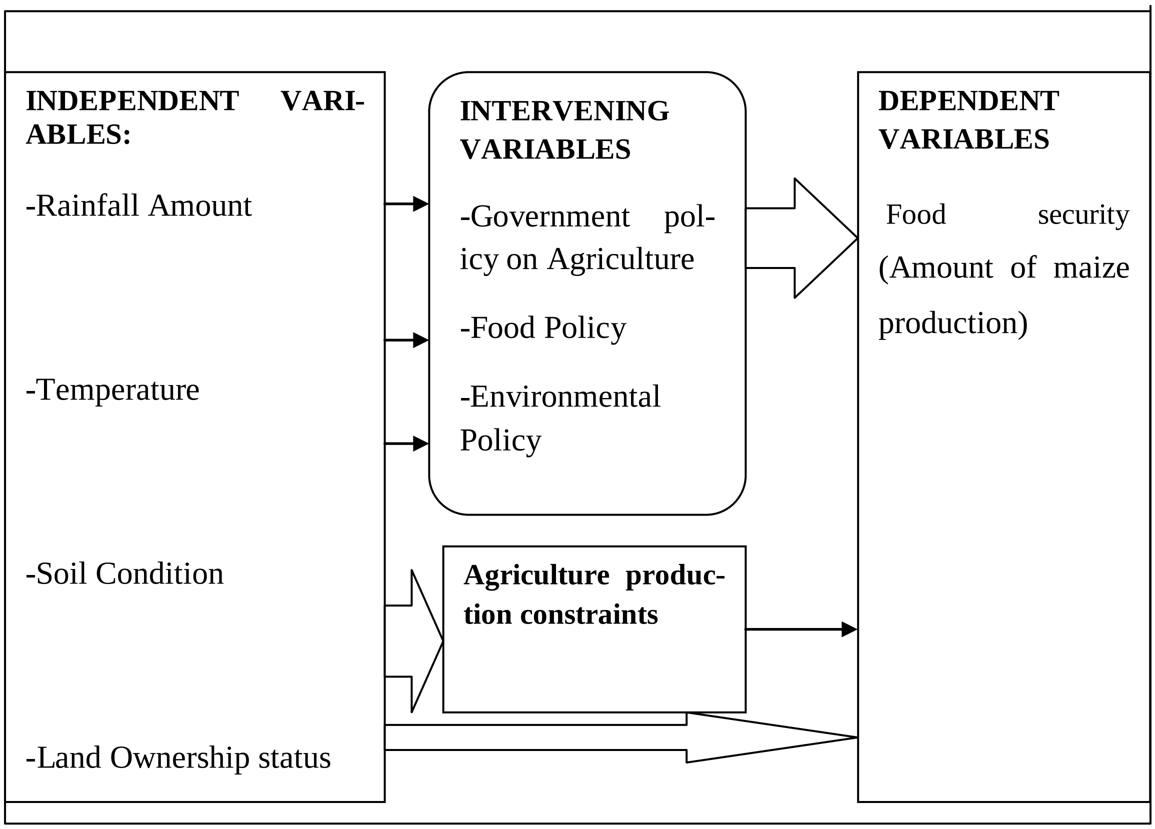

Fig 2.1 Conceptual framework for a proposed study. Adapted from: Adedoyin and Adeokun (2004).

This study sought to establish the contribution of climate variability on maize production in Siha district, Tanzania. There are two primary components, which are independent variable that is, the rainfall amount, temperature, soil productivity condition, and land ownership. The dependent variable in this study was food security, which was operationalized into yearly maize crop production amount in tonnes by the farmers. The dependent variable is measured by the components of tonnes of maize as shown in **Figure 2.1**, and was hypothesized as a driver of food security in Siha district in terms of agricultural productivity that can ensure nutrition and energy supply to human requirements in Kilimanjaro.

The relationship between the variables was perceived to be intervened by Food Policy, Government Policy on agriculture and environmental policy. This implies that the intervening variables can directly or indirectly affect the independent and dependent variables. This is to say that if government policies such as agricultural subsidies, taxes, infrastructure and extension services (as reflected in the agricultural Reform Policy), environmental management policy and Food Policy are not given enough attention; they may lead to the negative impact on both climate variability and maize production to farmers as measured in tonnes and may distort food security indicated by the level of maize crop production yield in tonnes per year. These include global warming, lack of agricultural personnel, lack of grassroots born policies, and lack of sustainable loans.

Climate variability results from a change in climatic elements such as rainfall that any change in climactic elements such as rainfall, will indicate a change in the level of rain-fed agricultural crop production. The relationship between these factors is that temperature influences plant growth as it affects physiological processes such as photosynthesis, transpiration, respiration, germination, and flowering. The physical rationale behind the relationship between rainfall and temperature is that rainfall may affect soil moisture which may, in turn, affect surface temperature by controlling the partitioning between the sensible and latent heat fluxes. Based on Figure 2.1 above it is assumed that when there are unpredictable rainfall variations and temperature changes, contributing to poor crop production (maize yield) it will lead to food insecurity. Intervening variables in the form of agricultural policy, food policy and environmental policy through relevant instruments like subsidies, extension services, and environmental protection measures can play role of mitigating climate variability to ensure reliable maize crop production and food security. This is going to be tested by the Production Function Approach and the Ricardian Approach. The two approaches are used simultaneously as complement each other particularly in shortcomings as explained earlier.

2.7 Research Gap

The study has surveyed on literature review where it touched the significance of environmental variables of production function in estimating the impact of climate as determinant of agricultural production and food security. Later it focused on the role of adaptation measures that influence soil productivity and land ownership. In this section it was established that there is significant role that climate factors and adaptation measures play in influencing agricultural production and food security, however, good the agricultural and food policy is, due to less effectiveness in implementing it, the farmers can be left in less productive and in food insecurity conditions as the climatic conditions are beyond human control.

The central production and Ricardian theories reviewed in this study contains several implications that can help the formulation of policies for agricultural development ad food security. These theories are discussed with the view that environmental variables and adaptation measures retain their significant effects on food security, whether positive or negative. The knowledge gap determined here is that there is currently no study which has been conducted in Tanzania in terms of scope of using the selected theories to determine the role of climate variability on maize production to farmers using quantitative approach which realistically measures food security components.

After that, the study shifted to review two policies which are in one way or another connected to food security. These policies are the Agricultural development Policy, and The Food Security Policy.

In retrospective, all policies were not participatory in nature, since none of them have claimed to have involved the grassroots farming communities. Secondly all these policies are in a ‘way fragmented,’ as none of them has consciously tried to mainstream the components of the other. For example, one would expect food security policy to be quoted in the agricultural development policy.

Another major research gap in literature was in terms of methodology, it has been discovered that most of scholars discussed here have employed qualitative approaches in collection and analysis of primary data alone. The current study has employed mixed research methods whereby the qualitative approach has covered five years (2014-2018) and quantitative approach has covered a period of 31 years (1989-2018).

In reference to empirical literature particularly focussing in Tanzania, it has been evident that most studies have focussed on semi arid ecological zones, others focussed on southern and central part of Tanzania. Additionally, other focussed on Isles (Pemba). It was clear only one study focussed in North east-particularly Kilimanjaro Region. So the current study finds validity to be studied because of their scarcity of related studies in the North-East area, particularly Siha District, Kilimanjaro. Also, this study is going to be more specific by focusing on only one crop-Maize on how its production has been affected by climate variability in the last 30 years.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The term methodology means the system of explicit rules and procedures in which research is based and against which claims of knowledge are evaluated (Ojo, 2003). The research methodology has two interrelated parts that is, the research design and data collection methods. This chapter on research methodology describes the research area of the study, research approach, research design, and population of the study, the sample and sampling procedures. The chapter also discussed data collection methods and tools which were employed in answering the research questions, data analysis and issues related to data credibility. The study was conducted in two selected wards within Siha District.

3.2 Research Design

Research design involves the planning, organization, collection, and analysis of data so as to provide answers to questions such as: what techniques will be used to gather data? What sampling strategies and tools will be used? And how will time and cost constraints be dealt with (Leedy, 1993). The researcher used the descriptive concurrent mixed method to gather data relating to the Effects of Climate Variability on Maize Production. The quantitative approach entailed a descriptive survey that aimed at describing the distribution of a phenomenon in a population and thereby establishing the facts (percentages and frequencies). According to Saunders *et al*. (2003) descriptive survey has a broad appeal for planning, monitoring and evaluating policies. Price, (2001) says that any researcher who adopts the descriptive research design attempts to produce data that is holistic, contextual, descriptive in depth and rich in detail.

On the other hand, a qualitative approach entailed a case study design that falls in the qualitative approach designs is used in this study. It is selected in this study due to the fact that it contains several characteristics that enable the researcher to access information and meaningful analysis of data for better understanding of the phenomenon of climate variability on how it affects maize crop production in Siha district. A qualitative approach allows the researcher to integrate face to face with respondents using the known language seeking to understand the situation in their own habits and captures the realities that survive. The researcher interprets the issue in terms of the meanings given by respondents (McMillan & Schumacher, 2010). Hence, within this context, the choice of qualitative research is particularly important for this because it could contribute towards policy development in the agricultural sector especially in the rural areas where the farmers are the majority.

3.3 Study Area

The study was conducted in Siha district, Tanzania. Siha District is one of the seven administrative Districts of Kilimanjaro Region in Tanzania. According to (Munishi *et al*. 2006) the District is bordered to the West by Arusha Region and to the East by Rombo and Hai Districts. The western part of Mount Kilimanjaro is located within the district's boundaries. The District was part of Hai District which was separated in 2007. It covers approximately 1,158 square kilometers (447 sq mi). Its geographic coordinate lies between Latitude 3°04’14.4”S (-3.0706600°) and Longitude 37°03’’42.9”E (37.0619300°). The area is made of 12 wards which are Biriri, Gararagua Ivaeny, Karansi, Kashashi, Livishi, Makiwaru, Nasai, Ndumeti, Ngarenairobi, Olkolili and Sanya Juu. (www.sihadc.go.tz)

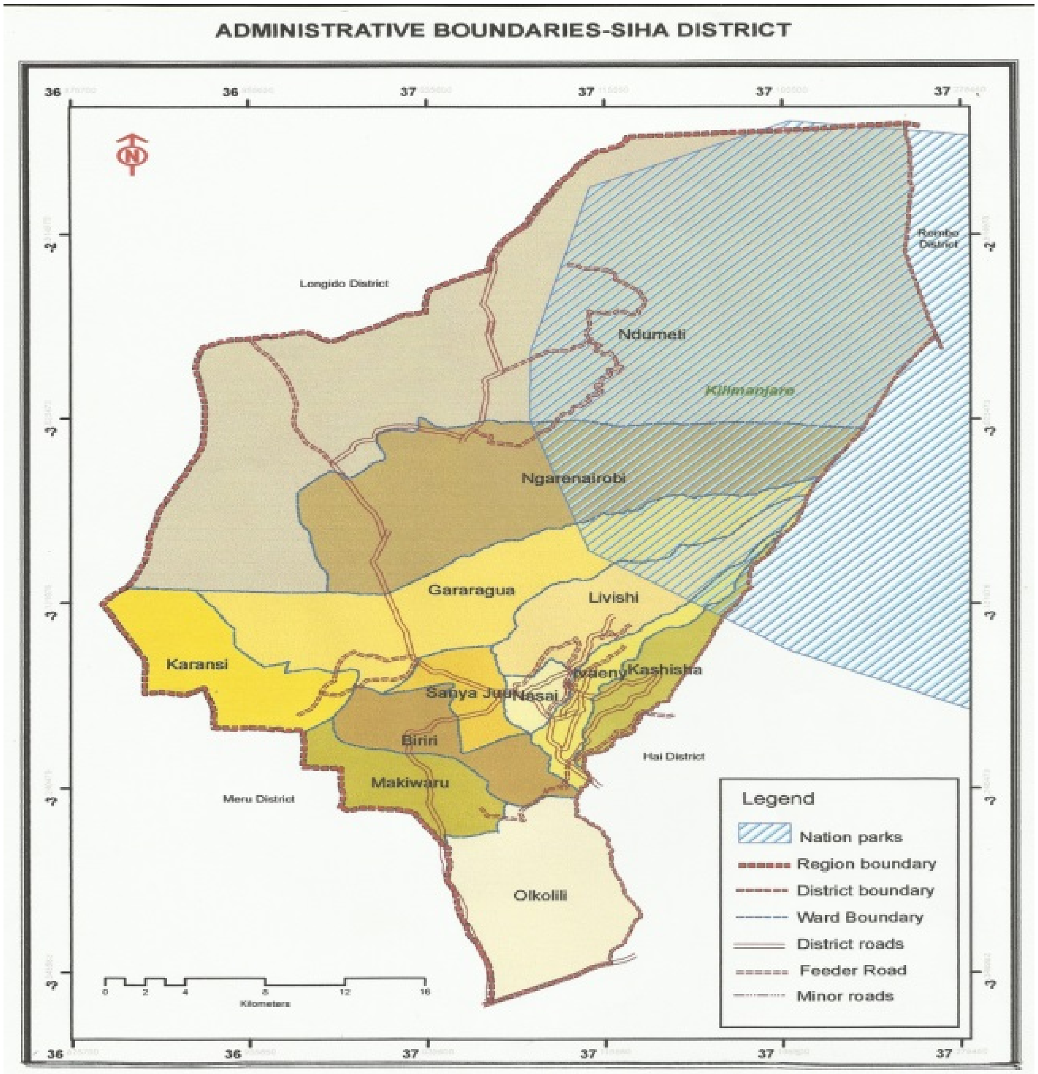

Figure 2:2, The map of Siha District showing location and neighbors (Source: www.sihadc.go.tz)

3.3.1. Climate and Topography

The research area is classified according to the Köppen climate system (Ackerman, 1941). This classification indicates a tropical, temperate continental climate (Pidwirny, 2006). Mean monthly temperatures range from 18.2°C in July to -21°C in January. Record high temperature reached 25°C, the record low temperature amounted 17.5°C (measurements until 2019).

The largest part of the Siha District is covered by Mt.Kilimanjaro slopes and plains. This district relative to other Kilimanjaro region districts has increasingly become, and has always been, more or less densely populated – even up to an altitude of 1,800 m above sea level (Munishi *et al*. 2006). Due to the presence of hills, streams of rivers springs and surface dams land has become very scarce in the district, and has forced out-migration to other districts ofKilimanjaro region. A smaller part of the lowlands in the west comprises of marshland, which drains into Pangani River. Contrary to the dry Maa-sai plains, this part of the lowlands can be cultivated. In the mountain areas farming is based on the cropping of bananas, sugarcane, coffee, potatoes and yams, whereas in the lowlands the majority of the populations, including the nomadic Maasai, are cattle-keepers, and maize cultivators. The Siha district has typically two distinct rainfall sea-sons; August to October and February to May, with the driest months occurring between November and January. Rainfall decreases rapidly with increase in altitude.

Nevertheless some climatic challenges include unreliable rainfall, for example the district did not receive short rains in 2014 and part of the 2016 short season resulting in an extended dry period. Some areas e.g. Biriri experienced poor rainfall throughout the year. This was attributed to changing climatic conditions. That is dependent on rainfall for agriculture; the area is relatively flat and relies on flood waters from the mountain sides for farming. Within the same district, there are areas that do not rely on rainfall for agriculture, for example Karansi. The area has established irrigation schemes and trenches that support farming throughout the year.

Another climatic challenge experienced in some parts of the region is flooding during the long rains. Areas such as Olkolili experiences floods in April to June, this sometimes results in loss of crops. Crops that do not require a lot of water e.g. potatoes are affected. In the low-lying areas of Siha districts, the biggest climatic challenge occurs during the rainy season when floods destroy the roads making transportation difficult. This occurs during the long rains, and affects transportation of agricultural produce as well as accessibility to basic services e.g. health services. The southern part of Siha district is occupied by the Maasai who are pastoralists, and during the rainy season, the main livestock market in the area gets flooded thus stopping all business activities until it is dry.(www.sihadc.go.tz).

3.3.2 Drainage Patterns and Vegetation

About 45.7% of the total land area is arable, 15.3% under grasslands and rangelands, 12.4% and 2.3% under dams and rivers respectively. The actual land use is however highly influenced by rivers, springs and surface dams that are used for irrigation, domestic purposes, and industries. There are three distinct agro-ecological zones based on altitude, soils and climate. The zones include the slopes of Kilimanjaro Mountain (1,800 to 5,895 metres above sea level.), the Highlands (900 to 1,800 metres above sea level) and the Lowland /Plains (below 900 metres above sea level). The lowlands provides fertile volcanic soils in origin, generally rich in magnesium and calcium, in addition to fertile soils, favorable climatic conditions and closeness to the equator at high altitude position the district's tropical and temperate good conditions for crops and dairy farming. Vegetation on the adjacent to Kilimanjaro Mountain is montane rain forest, degrading to woodlands and then open grasslands and shrubs in the plains and along the slopes.

The district may be divided into three agro-ecological zones, namely, the Lowlands (1,500 m and below); the Highlands (1,500-3000 m); and the Forest (above 3000 m). With the exception of land above 3000 m, most of the land can be used for agricultural activities. Agricultural land on the other hand can be classified into three main zones: The Coffee zone, which can grow coffee, bananas, maize, beans and dairy cattle. The Wheat zone, where the agricultural activities include Wheat, beans, maize and dairy production. The Lower zone includes areas suitable for ranching as well as areas suitable for maize, cotton, beans and paddy.

3.3.3 Population

The Tanzania 2019 National Bureau of statistics (NBS) estimated the population of Siha district at 494,310 and that of Kilimanjaro region as a whole at 2,140,087. Majority of the population, 75% in Siha and 67% in Kilimanjaro live in the rural areas. The farming population, in Siha district, is around (52%) compared to (48%) of the whole region. As indicated by the figures, the population of adults (18+ years) is 52% in Siha district and 55% in the Kilimanjaro region. Sanya Juu ward, Kashashi and Makiwaru has the highest while Ndumeti, Karansi and Olkolili have the lowest adult population in comparison. (www.sihadc.go.tz)

3.4 Population of the Study Area

The population is the set of elements that the research focuses up on and to which results obtained by testing the sample should be generalized (Bless and Higson-Smith, 1995). Sebstad *et al.* (2006) defined characteristics of a study population as it involves members of the study that is used to provide pre and post data on selected indicators of knowledge, skills, and attitudes of members towards exposure to learning events.

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3.5 Targeted Population of the Study

The target population is "the entire aggregation of respondents that meet the designated set of criteria" (Burns & Grove, 1997:236). The target population in this study constituted all adult maize farmers between 18+ years in Siha district, key informants (District Agricultural and Meteorological officers) and household heads (farmers) in Siha district.

3.6 Sample size and Sampling Procedure and Techniques

3.6.1 Sample Size

A sample means a specimen or part of the whole population drawn to show what the best are like (Naoum, 1998). Kothari (2004) defined sample size as the number of items to be selected from the universe to constitute a sample. In order to get the data, a purposive sampling procedure was used to select the sample. To accomplish this task effectively and efficiently the researcher obtained information from a total of 92 respondents, due to time limits and also because the researcher will be dealing with agricultural activity and climatic conditions, 3 agricultural officers were interviewed and 2 officers working in the Meteorological station of KIA (Kothari, 2004).

In determining the sample size the researcher used Krecjie and Morgan Chart (1999). Based on this chart if the population ranges approximately at 100,000 then the sample size ought to be more than 30 persons. So based on (NBS 2019), Siha district had a population of 494,310, there it is arguable justifiable to have a sample size of 92 household heads (See Appendix V).

3.6.2. Purposive Sampling

Mason (1998) argues that purposive sampling is a set of procedures where the researcher manipulated the analysis, theory and sampling activity interactively during the research process to a much greater extent than in statistical sampling. Kothari (2004) shows that purposive sampling is a deliberate selection of particular units of the universe for constituting a sample, which represents the universe.

In order to achieve the objective of the study, all the 12 wards in Siha District provided 92 respondents who were old enough to determine the trends of climate variability in relation to maize crop production. The minimum age of the respondents was at least 45 years of age and must have spent most of their lives in Siha District. This was meant to apply for household heads. Moreover, non-probability sampling technique which is purposive sampling procedure was used to select government officials such as District Agricultural and Meteorological Officers, Ward Executive Officers. These samples are expected to provide detailed information related to agricultural activities and climate changes taking place in the study district and their contribution to food security in Siha district. So in addition 92 household heads farming maize, there were 2 Ward Executive Officers, 2 District Agricultural Officers and 2 Meteorological officers. In total, there were 6 purposively sampled respondents for Key informant interview.

3.6.3 Simple Random Sampling

This technique gave each element or individual an equal and independent chance in the population of being selected into the sample (Krishna, 2003). The justification of using simple random sampling is not only easy but also reduces bias by ensuring that a quota is adequately presented. Therefore, basing on his definition a researcher gave an equal chance of maize agricultural farmers to be selected. Therefore, the selection of the study respondents based on simple random sampling as a probability sampling technique can be employed to capture adequate information from the respondents. So in the implementation of this technique, the researcher included the wards to be used through this technique. The researcher wrote twelve names on a piece of paper and cut them separately and put them in a jar. After tossing, two wards Biriri and Ndumeti were selected for providing ward officers. A purposive sampling technique was used for selecting household heads from village logbooks (register book).The sampling unit was household heads. Household heads was selected because in most cases, they are decision makers at household level.

3.7 Data Collection Procedures

3.7.1 Types of Data

This section bears two major types of data which are primary and secondary data. The primary data are data or information collected afresh and for the first time and this happens to be original in character. The secondary data, on the other hand, are data that have been collected and used by someone else and passed through a statistical process. It is better to collect both secondary and primary data as Shipment (1995) suggested that no single data collection technique is considered adequate for collecting valid and reliable data.

Thus different methods of data collection were involved in this study such as administered questionnaires for 92 maize farmers in Siha District, interviews data were gathered from 2 ward executive officers, 2 district agricultural officers and 2 meteorological officers, questionnaires and interview instruments collected primary data. Finally the documentary reviews were used to obtain secondary data from 1988 to 2018 on time series variables in our study.

3.7.2 Documentary Review

The researcher used a documentary review to collect data on production trends, rainfall, and temperature from Siha District Council (Agriculture department) and Kilimanjaro Meteorological Authority (KMA). According to Fraenkel and Wallen (1993), the method was useful because it helped in further extending the answers, which was particularly important and revealing. The data which was collected from this instrument was maize crop production over 30 years, temperature and rainfall data over 30 years.

3.7.3 Interviews

The interview method was used to 6 key informants; 2 ward executive officers, 2 district agricultural officers and 2 meteorological officers. The Interview used both open ended items. This method was considered relevant for this study basing on its theoretical underpinnings of interviewing respondents. The Interview method was particularly useful in the collection of rich qualitative data due to their flexibility, being focused and time-effective (Patton, 2002). The information obtained from the interview was maize production trends and its challenges, effects of climate variability in the village, mitigation measures and experiences from the field regarding climate variability and maize production. This method allowed greater flexibility for both the informants and the researcher and it was dynamic enough to ensure that issues were properly discussed and addressed.

3.7.4 Questionnaires

The questionnaires were designed to capture relevant information for study questions under investigations. Household head respondents were provided with questionnaires and responded accordingly. The researcher prepared questions and asked the respondents to respond according to their understanding of the phenomenon. This method was used to collect information from household heads. In this study, questionnaires were employed to gather information from the respondents so as to trap their perception in regard to the effects of climate variability on maize production, temporal variability of rainfall and temperature as well as adaptation strategies. The 92 participants were free to provide their views on how they understand climate variability and maize production strategies in their areas.

3.8 Data Analysis and Presentation

3.8.1 Analysis of Quantitative and Qualitative Data

According to Kothari (2004), data analysis refers to editing, coding, classifying and tabulation of collected data. The quantitative data analysis involves the analysis of numerical or statistical measurement. The process of recording involved the use of questionnaires where the respondents were required to provide their correct answers.

Thus, the collected data were first being coded and analyzed using the Statistical Package for Social Science (IBM-SPSS) version 19.0. SPSS was used to generate frequency and percentages. Frequency distribution tables were used to present data in a summary form, while percentages were used to reduce masses of data to a form that is quickly under stood. Tables are used to compare data during the interpretation of those data because are easiest and commonly used in analyzing and interpreting collected data and easily to draw conclusion and come up with recommendations.

Data presentation involved the use of tables, graphs, and percentages. This approach enabled the reader to gain knowledge easily. Hence, the discussion of findings, conclusions, and recommendations was based on the interpretation of tables, graphs, and percentages**.**

On the other hand, qualitative data was procedurally analyzed first by the collection of data. As indicated earlier, the researcher used face-to-face interviews. After that, data transcription followed. This is the transcriptions of audio files into Microsoft Word files by translating them from Swahili to English then it was ready for coding.

After data transcription, the next step was to apply qualitative data analysis through constant comparison of emerging themes. Before this is done the coding process had to take place first. (Sarantakos, 2005) defines a code as a symbol or a set of symbols used in measurement and analysis in the place of responses collected through social research. Data coding is defined by social scientists as finding "tags for assigning units of meaning during the study. Codes are usually attached to chunks of varying size – words, phases, sentences, or whole paragraphs connected to a specific setting" (Neuman, 2006).

When the process of coding was done, the final step of the analysis was ushered where codes under the same research questions were compared to establish the continuities or discontinuities of ideas. Also, the researcher was observant of the unsaid stories because they have the potential to bring out important meanings.

3.8.2 Analysis of Metadata

Regression model

Since the bulk of the agricultural production is dependent on land characteristics and climatic conditions, variations in the maize farm productivity in Siha District likely reflect variations in soil type and in climatic conditions in terms of temperature and rainfall.

In an early exercise Rodolfo et al. (2010) made a multiple regression analysis of time series on the basis of the Agricultural statistics services data (ASS) for 41 years (1969 – 2009) and observed that agricultural production growth varied directly with its land characteristics and rain fall amount, inversely with its temperature variability.

Raphael and Wilson (2015) related interregional variations in agricultural production to those in the irrigated farmers in India. On the basis of the (ASS) region wise data for cross-section analysis, they estimated a region model to explain interregional variations in the overage production volume in terms of differences in variable like agricultural productivity per hectare (AGHA), in turn were affected by the amount of water irrigated use of natural manure and artificial fertilizer temperature and rainfall. They observed that the NSC was the most dominant variable for explaining variations in the (AGHA) across regions which in turn, were primarily responsible for inter-regional variations in the farm produce using the region-wise ASS data for the 6 regions of country Zungo (2017) and Godfrey (2010) explained farm production in terms of institutional, Infra-structural and technological factors that determine the pattern of agricultural growth. One of their findings was that regions with applications of modern technologies and favorable institutions in infrastructure had high agricultural growth rates and high agricultural output per farmer.

Logistic Models

An interesting approach to study the factors influencing agricultural production is the application of the log it model to Cross-sectional data. In this approach, agriculture productivity is treated as a random event whose occurrence is assumed to depend on a number of variables of which some are farm specific others are general characteristics like cropping intensity.

Soil productivity and available infrastructural and institutional facilities in the area), assuming agricultural productivity of the i^{-th} farmer depends on the values of K variable (X_il, …….., X_ik) corresponding to the i^{-th} form in the following way:

AHP^{β}………………………………………………………………………………… (5)

Where β = (β) is a k - component (row) vectors of parameters (to be estimated), Xi = (X_ij) is the k - component (column) vector of explanatory variable corresponding to the

i^{-th} farmer (with Xi equaling 1 to take care of the constant term in the equation and U_i is a random disturbance term for the i^{-th} farmer with a 0 mean and other properties assumed.

Let Z be the given minimum production of maize so that the 1- Farmer is said to have poor maize produce if $AHP_i < Z$. Let y, be a dichotomous random variable which takes the value 1 if a specified event occurs (in this case, if the i-th farmer has poor harvest) and O, otherwise. Let P_i be the probability that the i^{-th} farmer has a poor harvest, then.

$P_i = P(y_i = I) = P(AHP_i < Z)$

Where F is the distribution function of U_i, One gets a logit model if F is logistic as U_i is standard normal, N(0,1) one arrives at a probit model; $F(W)=\ell^{w} /(1+\ell^{w})$.In the case of logit model, therefore one gets.

$$P_i = \ell^{Z - \beta xi} / (1+\ell^{2 - \beta x_i}) \qquad (6)$$

The odds that the 1 – the farmer's harvest is poor is given by the ratio $P_j/ AA(1 - P_i)$ and the logarithm of this ratio can be shown to be a linear function of the explanatory variable.

Further, $$\frac{\partial P_i}{\partial X_{ij}} = -\beta_j P_i (1-P_i) \quad (j = 2, \text{-----------}, k) \qquad (7)$$

So if $\beta_j > O$, the probability of farmers harvest falling below the poor harvest line decreases with an increase in the value of X_{ij}. Where X_{ij} is the values of the explanatory variables with β parameters, estimation conforming to the Maximum likelihood method of $AHP = \beta_0 + \beta_1 X_1 + \beta_2 X_1 + \beta_3 X_3 + U$ …………………………………………… (8)

The coefficient parameters are expected to be positive and U is distributed around the mean.

The method of maximum likelihood is used to estimate the parameters of the logit model. The maximum likelihood method chooses a set of parameters to maximize the likelihood that the actual choices, represented in the dependent variable would actually occur given the set of independent variables facing the producer. For each maize agricultural farmer with a total of n farmers and where d is a binary variable equal to 1 if volume j of maize was harvested by the farmer 1 and 0 if otherwise. The joint probability of likely

n J-1hood (L) for J choices is $L = A\ \Pi\ x\ \Pi\ d_{ij}\delta_{ij}$

i=1 j=0

Taking the log of this equation yields the log likelihood function.

$$\ell nL = \sum_{i=1}^{n} \sum_{j=0}^{J-1} d_{ij}\delta_{ij}$$

When j= 0 the marginal effect is $\frac{\partial \delta_0}{\partial \ddot{X}^{\wedge}} = -\partial_0 \sum_{k=1} \delta_k \frac{\partial q_k}{\partial \ddot{X}}$

Elasticities, w, for the maize crop production outcome are computed as

$$w = \frac{\partial \delta_i}{\partial x^\wedge} X^\wedge$$

Where X^ is the value of the independent variable at which the probability is computed by a specific equation

$$\log \left[\frac{AHP}{1-AHP} \right] = \beta_0 + \beta_1 \log RFA + \beta_2 \log TMP + \beta_3 \log SOP + \beta_4 \log LOP \quad \ldots\ldots\ldots\ldots.. (9)$$

The parameters β_0; β_1; β_2 are all said to be positive, SOP is the soil potentials for maize agricultural farm and LOP is the land ownership category and AHP is the average harvest of a maize farmer

Hypothesis testing

To test if an individual independent variable is significantly impacting the log likelihood function; the standard t-test is applied just as in the ordinary least squires (OLS) regression models. There are three key statistics that measure whether multiple independent variables are significantly making an impact on the log likelihood function the likelihood ratio (LR) statistic, the Lagrange multiplier (LM) Statistics, and the Wald test. These three test statistics are distributed according to the Chi-square distribution with degrees of freedom equal to the number of restrictions being tested.

Goodness of fit measures

There are three commonly used measures to indicate the goodness of fit of multinomial models. Pseudo R^2 and Count $R^2{}_1$. The above objectives of estimating and analyzing models of maize production as stipulated above can be achieved through the econometric procedures stated, the present study had been carried out on the basis of primary and secondary data pertaining to the period 1988 to 2018 that are collected for various sources (Siha District department of Agriculture, and the weather data at the KIA meteorological station)

Appropriate non-linear time series model was fitted after judging the time series data for stationary based on a visual inspection and the autocorrelation function that non putative lags were worked out. The statistically most appropriate time series model was selected based on various goodness of fit criteria viz. AIC, BIC, normality test and test for randomness.

In the log it model, the first step involved estimation of optimum likelihood computed by calibration and cross validation method. Estimates of underlying maize production to individual farmers were computed using cross sectional data of 2018 for 92 maize farmers of Siha District. Residual analysis was carried out and subjected to hypotheses testing and a relative growth rate was calculated based on the best fitted model.

3.9. Validity and Reliability of Instruments

3.9.1 Validity

In the context of research design, the term validity means the degree to which scientific explanations of phenomena match the reality. It refers to the truthfulness of findings and conclusions. Explanations about observed phenomena approximate what is reality or truth, and the degree to which explanations are accurate comprises the validity of design (McMillan & Schummacher, 2010). Likewise, the questionnaire was validated by experts in educational management research department whereby objectives of the study were shared with him and the questionnaires made and gave him room to advice before the researcher continued with the next stages and generally

3.9.2 Reliability

According to McMillan & Schumacher (2010) reliability refers to the consistency of the measurement-the extent to which the results are similar over different forms of the same instrument or occasions of data collection. Another way to conceptualize reliability is to determine the extent to which measures are free from error. If the instrument has little error, then it is reliable and if it has a great amount of errors, then it is unreliable. Reliability has to do with the accuracy and precision of a measurement procedure.

The research validity was measured through the results obtained by a Pilot Test which was done on March 25, 2019, in one private school in Arusha. Thereafter the results from 30 respondents were coded in SPSS and Cronbach's Alpha 0.87 was obtained inferring only minor adjustments were to be done before data collection.

3.9.3 Ethical Considerations

Research ethics refers to the application of moral standards to a decision made in planning, conducting and reporting the results of research studies. The researcher obtained a research clearance letter from the office of the Director of Post Graduate Studies of the Open University of Tanzania. The letter enabled the researcher to seek permission letter from Siha District Executive Director and Manager TMA-KIA to allow the researcher to conduct research in the study area as well as data access.

The researcher introduced himself, described the study, its purpose, and benefits, the category of interviewees, steps to be taken to maintain confidentiality and notify them about the duration of the interview. On completion of each interview session, the researcher expressed appreciation to the interviewees for their cooperation and participation. Prior to data collection, the researcher ensured that the data collection instruments are approved by the supervisor.

In addition, respondents were informed about the nature and purpose of the study. By so doing, the researcher informed consent from respondents for their participation. The study also put into consideration respondent's privacy and willingness of respondents as well as truthfulness, reciprocity, thoroughness, objectivity, and relevance principle were both applied in all procedures in planning, conducting and reporting the results. All these applied to morality in research.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the finding of the study, data analysis and discussion of the findings. The findings are presented using simple statistical methods like simple frequencies and percentages presented in tables and figures.

4.2 Socio-Demographic Characteristics of the Respondents

4.2.1 Gender of the Respondents

This section provides the characteristics of respondents in terms of gender. This was done to assess the distribution of respondents by gender. In this study, more than half of respondents 56.5% were males and about 34.5% were females.

Table 4.1: Gender of the respondents

Sex	Respondents	Percentage
Male	52	56.5
Female	40	34.5
Total	92	100

Source: Field Data, 2019

The result indicates that the society is well organized in terms of responsibility and there are no imbalances like in other areas where women participate more in agriculture than men. Therefore there is good distribution of work and men are busier in agriculture than women.

4.2.2 Age of the respondents

The age distribution of the respondent is presented in Table 4.2. About 4.5% of respondents were of the age group 16-25, and 8% had the age between 26-35 years. However, 13.6% of respondents had the age ranging between 36-45, 15.9% between 46-55, 38.0% between 56-65 and 21.7% were of the age 66+.

Table 4.2: Age of the respondents

Age categories	Respondents	Percentages
16-25	4	4.5
26-35	7	8
36-45	12	13.6
46-55	14	15.9
56-65	35	38.0
66+	20	21.7
Total	92	100

Source: **Field Data, 2019**

The sampled household heads were indicating that most were falling in the economically productive population in Tanzania which ranges between 15 to 64 years of age (NBS, 2013). In addition, the age of the household head can be used to capture the farming experience of the respondents since as shown by Maddison (2006) and Nhemachena and Hassan (2007) that there is a positive relationship between age of the head of the household and the chance of acceptance of adaptation measures to climate change.

The results revealed that the majority of the people in the study area were in the category of middle, adult and elderly age population, this indicates that since their decision makers can engage in agriculture production like maize, therefore, they can produce more. Also if they were educated they can help us to overcome the challenges of climate variability easily than others.

4.2.3 Marital Status of respondents

On the marital status, 16.3% of the respondents were single, 72.8% were married, 2.2% were Divorced and 9.8% were widowed (Table 4.3).

Table 4.3: Marital status of the respondents

Marital status	**Respondents**	**Percentages**
Single	15	16.3
Married	67	72.8
Divorced	02	2.2
Widowed	9	9.8
Total	92	100

Source: **Field Data, 2019**

The results indicate that most of the people were married thus they are caring for the family, likewise to the widowed. Also those who are single mostly are the young ones who fall to the productive group who produce for their own livelihood, economical gain as well as supporting their parents. Likely it is possible for them to understand the challenges associated with the effects of climate variability. Also, it's easy for them to adopt new technologies and other mitigation measures since more people depend on agriculture for their survival.

4.2.4 Education level of respondents

About 48.9% of the respondents had primary education, 6.5% had no formal education, 29.3% had secondary education, as well as 15.2% of the respondents, had tertiary education. (Table 4.4) The results show that more respondents in Siha District attended secondary school as well as primary level therefore the level of ignorance is extremely low.

Table 4.4: Education level of respondents

Education Level	**Respondents**	**Percentages**
Non-formal education	6	6.5
Primary Education level	45	48.9
Secondary Education level	27	29.3
Tertiary level	14	15.2
Total	92	100

Source: **Field Data, 2019**

Thus the implication of these results indicates that, the adoption of maize production technology, as well as mitigation measures to overcome the effects of climate variability, could be high due to the fact that more respondents are aware of the effects due to their education and more people depend on agriculture to improve their livelihood and for survival.

4.2.5 Occupation of the respondents

Table 4.5 shows that 43.5% of respondents engaged in agriculture (crop production) whereby 56.5% engage in agriculture (farming and livestock) for their livelihood (Table 4.5).

Table 4.5: Occupation of the respondents

Occupation	Frequency	Percentage
Agriculture(crop production)	40	43.5
Agriculture(farming and livestock)	52	56.5
Total	92	100

Source: **Field Data, 2019**

The average proportion of involvement of people in the maize farming activity occupies a substantial proportion of the residents of Siha when compared to other districts of Kilimanjaro region (Agricultural Report, 2017), although it seems that maize farming activity is superseded by livestock keeping however. This figure tells us that whenever unfavorable climate variability and policies prevail on agriculture a significant number of populations that depends on maize production are more likely to be negatively affected and plunged in food insecurity. This is a more pronounced state of life in Siha as modern and better farming practices have not taken ground.

4.2.6 Size and means of land ownership

The area under cultivation is on average of 2.1 acres of land cultivated per household which is slightly above the average utilized area for cropping activities per agricultural household in Tanzania which is 2.0 acres of land (NBS, 2013).In this area, about 75% owns the land whereby 25% depends on leased land.

Table 4.6: Means of land ownership

Occupation	**Respondents**	**Percentage**
Owns land	69	75
Leased land	23	25
Total	92	100

Source: **Field Data, 2019**

The area under cultivation is shown in Table 4.7, and on average 2.13 acres of land being cultivated per household which is slightly above the average utilized area for cropping activities per agricultural household in Tanzania which is 2.0 acres of land (NBS, 2013).Also every household owns an average of 1.85 acres of land with approximately 2 acres and hire the extra land to reach 2.13 acres.

4.3.1 Influence of temporal variability of rainfall on maize production

An analysis of the prediction of independent variables indicated that the average rainfall amount was the variable that had an influence on the estimated maize yield. Its coefficient value is positive, which indicates that a higher average rainfall amount indicates a higher maize yield and vice versa. This variable has a positive coefficient, indicating that a one percent increase in rainfall amount is associated with an increase of 0.208 percent in maize production yield if other things remain constant. It should be also noted that the t-value have exceeded the t = 2.0 rule of the thumb. These variables employed in this study were used following Hoogenboom (2000) recommendation, which indicates that the agro meteorological variables affect crop development.

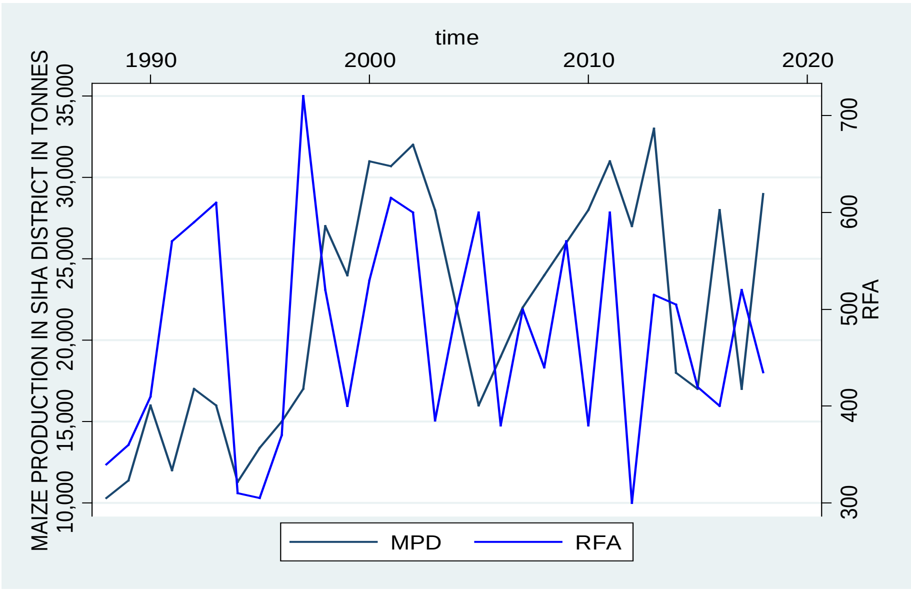

Figure 4.3: Trend Analysis of Maize crop production growths with respect to rainfall variabilities in Siha District for thirty years (1988-2018)

Source: Stata Output, 2019.

From figure 4.3 it is clear that the series of maize production varies positively with rainfall amount and the variation is more or less stable throughout the time series period and no significant except for a few years of 1997/98 and 2002 where the rainfall amount was significantly high, this was in correlated the maize production series that experienced high production from 1998 to 2002 and 2002 to 2004.

4.3.1 Non-Stationarity Tests

The casual observations of graphs of all variables series in the study do not include a trend term. The study used the Augmented-Dickey Fuller test which is one of the most commonly used tests stationarity that is the absence of a unit root. Having unit root in a series mean that there is more than one trend in the series. In these tests, the null hypothesis is that the series has a unit root. All tests of unit roots (Augmented Dickey-Fuller and the Phillips-perron tests) revealed that variables are stationary at levels.

Table 4.7....... **Unit Root Tests for the Five Variable Series**

Variable Series	ADF(1)	ADF(2)	ADF(3)
(1)	(2)	(3)	(4)
MPD	-4.969 (-3.576)*	-5.8887 (-3.580)*	-2.496 (-1.584)
RFA	-2.876 (-3.576)*	-1.946 (-1.580)	-1.433 (-1.584)
TMP	-3.991 (-3.600)*	-3.464 (-3.600)*	-1.146 (-1.600)

*****Symbolize significance

The next step was to estimate the long run relationship of variable series in the equation.

Table 4. 8...: Correlation of temperature and rainfall variations on maize production

		Maize production	Rainfall	Temperature
Maize Production	Pearson Correlation	1	.334**	.515**
	Sig. (2-tailed)		.009	.000
	N	60	60	60
Rainfall amount	Pearson Correlation	.334**	1	.027
	Sig. (2-tailed)	.009		.839
	N	60	60	60
Temperature	Pearson Correlation	.515**	.027	1
	Sig. (2-tailed)	.000	.839	
	N	60	60	60

Source: Field Data 2019

The hypothesis was tested through Pearson product Moment Correlation Coefficient. The nature of existing correlations between the variables would be either positive or negative and was interpreted based on the following criteria: ≥ .70 = strong relationship, ≥ .50 = moderate relationship and ≤.50= weak relationship. With a Pearson Correlation of .334 (Sig. of .009), there is a weak yet positive correlation between maize production and rainfall amount. Therefore, the rainfall amount positively influences the maize production in Siha District. Furthermore, with a Pearson Correlation of .515 (Sig. of .000), there is a moderate yet positive correlation between maize production and degree of temperature. Therefore, the degree of temperature is a determinant of maize production in Siha District.

4.3.2 Selecting Lag lengths

In order to trace the effects of one season weather condition on the other season production, the study employed the co integration analysis for the mentioned 30 years which requires knowing the exact value of independent variable in the past period which may have likely affected the current value of the dependent variable. Previous seasons in term of temperature and rainfall have bearing on production plans of the current season.

Table 4.9 On Lags Selection-order criteria

Lag	LL	LR	df	P	FPE	AIC	HQIC	SBIC
0	12.52				5.4e-06	-.774806	-.728075	-.576434
1	118.356	211.67	16	0.000	1.6e-09	-8.94146	-8.70781	-7.9496
2	143.668	50.624	16	0.000	8.1e-10	-9.788*	-9.3674*	-8.0026*

Source: Computed from Stata Output, 2019

The selection order criteria used a sample of 29 number of years observations (that is from 1990 to 2018) after including four years lag length, which means two initial years were to be excluded in the sample period Lutkepohl, (2005). The endogenous variable is a dependent variable according to the study model; this is an MPD; whereas the exogenous variable is a constant variable mentioned above. Current production plans of maize in Siha district is influenced by past two years. This validates the fact that maize farmers in Siha have medium term plans with regard to maize production influenced by temperature and rainfall variability.

The criteria used were the Akaike Information Criterion (AIC) that suggested 2 lag orders, Hannan Quinn Information Criterion (HQIC) suggested 2 lags orders and the Shwartz Bayesian Information Criterion (SBIC) suggested 2 lags orders be included in the equation. The HQIC and SBIC since have theoretical advantages over AIC and FPE (Nielsen, 2001; Lutkepohl, 2005). The 2 lags in the HQIC an SBIC have the lowest values and the study interest is to minimize the prediction error as displayed in the STATA output.

4.3.3 Co-integration Analysis

Co-integration refers to the fact that two or more series share a stochastic trend (Engle and Granger, 1987; Stocks and Watson, 2007; Green, 2008) suggested two processes to test for co-integration (the ordinary least square regression and a unit root test), the Engle-Granger-ADF test. The first task was to run the OLS regression whereby the integrating equation was identified. The second task was to get the residuals (e) and finally testing for the unit root of the predicted residual, and the results as displayed in the Stata output revealed that there is no unit root in both the regression equation and the residual therefore are co-integrated as evidenced by the p-value of Z (t) = 0.015 which is less than the rule of thumb 0.05.

The next step was to determine the co-integrating rank so as to be able to estimate the vector error correction model (VECM). At the maximum number of 2 lags in the model, the Johansen Test suggested co-integrating equation One (1) as indicated in the STATA output.

Economically speaking, two or more variables will be co-integrated if they have a long-run, or equilibrium, relationship between them. In the present context, agricultural theory tells us that there is a strong relationship between crop production and rainfall amount and temperature variabilities. In the language of co-integration theory, the equation that is $MPD = \beta_0 + \beta_1 RFA + \beta_2 TMP$ is known as a co-integrating regression and the slope parameters β_0, β_1, β_2 are known as co-integrating parameters for the equation.

The results for co-integrating equations are indicated. The header contains information about the sample, the fit of each equation and the overall model of fit statistics. The first estimation table contains estimates of the short run parameters along with their standard errors, statistics and confidence intervals. For results, the co-integrating equation is one in the study model. For the mentioned equation MPD has coefficients of 0.31153 for rainfall amount, 0.105 for temperature and z-statistics are 4.87, and 2.548 and the P-values of 0.000, 0.0035 respectively. Since all the terms in the VECM model are stationary therefore, the standard OLS estimations are valid.

The study findings in the regression model of maize production are in terms of climatic variabilities Vaughan et al (2000). The estimated equation reveals that maize production changes can be largely explained by the changes in climatic conditions. For the equation, the goodness of fit quality of 64 percent R^2, indicates that 64 percent of the variations in the maize production are explained by changes in the explanatory variables (rainfall amount and temperature).

4.4 Influence of seasonal variation of temperature on maize production

An analysis of the prediction of independent variables indicated that the average air temperature was the variable that had the greatest influence on the estimated maize yield. Its coefficient value is positive, which indicates that a higher average temperature indicates a higher maize yield and vice versa. The other variable has a positive coefficient, indicating an opposite effect from the average temperature, i.e., a higher maize yield as the variable increases and vice versa.

From equation (1) in the study model on maize production and the relationship to climatic variations reveal a significant statistical relationship in the 30 years period covered by the study (1988-2018). All the t-values on partial slope coefficients have t-values above 2.0 rule of the thumb.

More analytically we see that a one percent increase in temperature is associated with the decrease of 0.455 percent in maize production yield other things remain constant.

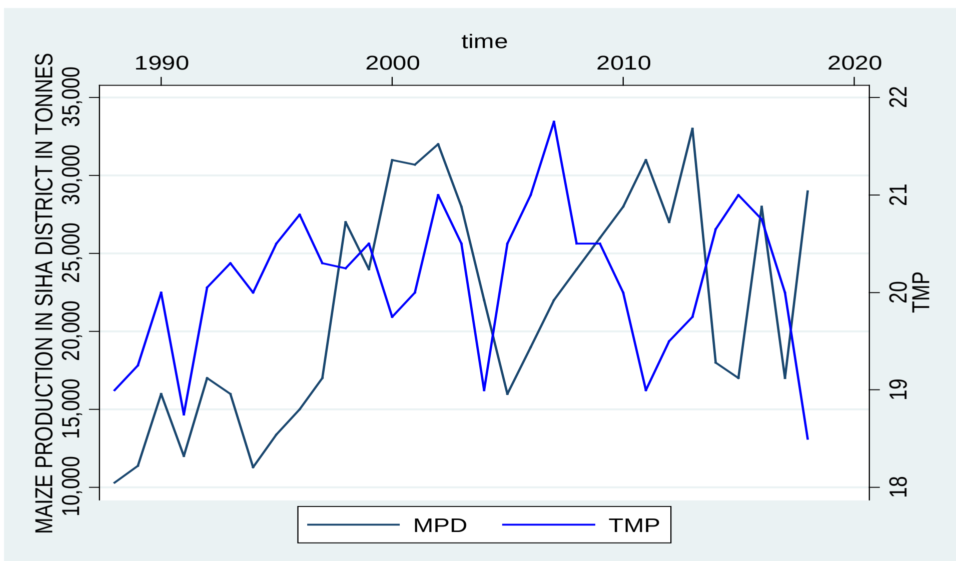

Figure 4.4: Trend Analysis of Maize crop production growths with respect to temperature variability in Siha District for thirty years (1988-2018)

Source: Stata output, 2019

From figure 4.4 it is clear that the series of maize production varies negatively with the degree of temperature and the variation is more or less stable throughout the time series period and no significant spikes. Except for a few years of 1993/94 and 2004/05 where temperature degrees were significantly low; this was in correlation to the maize production series that experienced high production from 1998 to 2002 and 2002 to 2004.

From the above results on variability of rainfall and temperature, different linear, non-linear and nonparametric regression models were employed to study the maize crop production trends in the study area. Data obtained for Siha district of Kilimanjaro region were employed. The characteristics of fitted linear, non-linear (Tables 4.1, 4.2. and 4.3) and time-series (Table 4) models are presented. The findings are discussed in sequence as under sentence.

To establish the effect and contribution of each element of climatic condition on maize production in Siha District, a multiple regression was adopted and the following descriptive statistics were obtained from each category.

Table 4.10 Descriptive Statistics on the quantitative variables

Variable	Mean	Standard Deviation	Variance	Skewness	Kurtosis	Min	Max	N
MPD	17.529	0.727	0.529	-0.289	1.493	15.459	18.495	30
RFA	17.058	0.852	0.725	0.355	1.809	15.001	18.554	30
$logR_3$	17.274	1.388	1.925	0.102	1.584	15.351	19.585	30

Source: Field Data 2019

According to STATA output, the data set consisted of 30 observations on three variables; Quantity of maize production in tonnes MPD, Temperature measures in °C (TMP), Rainfall measure in mm (RFA). The first variable is a dependent variable and the last two are independent variables. Summary statistics of mean, standard deviation, variances, Skewness, Kurtosis were used and are shown in Stata output.

The mean is the sum of the observations divided by the total number of observations. Standard deviation is the square root of the variance, indicates how close the data is to the mean. Assuming a normal distribution, 58% of the values are within 1 standard deviation from the mean, 95% within 2 standard deviations and 99% within 3 standard deviations. The variance refers to the dispersion of the data from the mean. It is the simple mean of the squared distance from the mean. Count (N in the table) refers to the number of observations per variable. Min is the lowest value in the variable and Max is the largest value in the variable. Additionally, according to the table, all variables data are normally distributed as the sum of Skewness and kurtosis in every variable is less than 3.0 values.

Graphing dependent variables and respective independent variables were made to explore visual inspection of trend relationships. As the below figure show that there is a certain trend pattern of the variables and in the stationarity test results all variables rejected the test for the presence of a unit root. Apart from the absence of a unit root, also no variable was discovered to have the problem of multicollinearity.

In all the three figures below it is revealed that maize production in relation to the independent variables (that is temperature and rainfall variations) are specified by a long run behaviour that is a trend characteristic in a time series. These trends seem to have long-run unpredictable pattern of variability over time.

4.4.1 Basic Regression Results on the maize production

After performing descriptive statistics estimations and their tests, the study conducted regression estimations. From STATA output, it was clearly seen that R^2s and P-values of MPD indicate good quality of fits. For the estimated equation the three explanatory variables in their natural logarithms explain jointly about 64.82 percent of variations in maize production for agricultural farmers in Siha District. It should be noted that all expressions are in natural logarithms. Here below is a model regression equation estimated results.

Table 4.11 Regression Results corresponding to the maize crop production

Dependent Variable: MPD				
Mean :				
Standard Deviation :				
Explanatory Variables	Regression Coefficients	Standard Error	t-Value	Significance at percent level
(1)	(2)	(3)	(4)	(5)
RFA	.455732	.086221	2.58	0.034
TMP	.208351	.0450143	3.15	0.025
Constant	15.57853	1.292835	3.211	0.024

Number of Observations = 30

$R^2 = 0.6482$, $F = 74.38637$ (from mean)

Residual Mean Square = .2241814

MPD = 15.57853 + 0.455RFA + 0.208TMP ……………………………… (1)

t	(3.21)	(2.58)	(3.15)
p	(0.024)	(0.034)	(0.025)

β_0^: linear coefficient estimation;

β_1^: estimation of the parameter related to average air temperature (ºC);

β_2^: estimation of the precipitation-related parameter (mm);

4.5 Marginal effects of temperature and rainfall on maize production

A marginal effect, or partial effect, in this study measures the effect on the conditional mean of volume of maize production of a change in one of the regressors, used in this study which is rainfall amount and temperature variability. Marginal effects are popular in some disciplines (e.g. Economics) because they often provide a good approximation to the amount of change in a dependent variable that will be produced by a 1-unit change in an independent variable. In the linear regression model used, the marginal effect equals the relevant slope coefficient, greatly simplifying analysis we take the estimated results of equation one;

$$MPD = 15.57853 + 0.455RFA + 0.208TMP$$

From the equation, it is clear that maize production depends on the climatic conditions given, that is rainfall and temperature as statistical coefficients indicate in t-values, which has statistically significant effects at 5% level of significance. From the equation, it is found that the marginal effect (1-unit measure of rainfall amount) produces 0.455 tonnes of maize production per annum other factors remain constant, which suggests that we may accept the assumption that the rainfall amount variation produces a significant effect on maize production for this maize production model at 5% level of significance. Again, it is found that the marginal effect (1-unit measure of temperature amount) produces 0.208 tonnes of maize production per annum other factors remain constant, which suggests that we may accept the assumption that the temperature amount variation produces a significant effect on maize production for this maize production model at 5% level of significance.

In this behavioural variation of the maize production and climatic conditions, it should be emphasized that whenever the climate fluctuates beyond the maximum and minimum level whether rainfall or temperature, the climate plays a role of negative effect on maize crop production. Since the crop is one of the measures of assuring that the population food supply is achieved therefore any climate variability that prevails beyond the critical values food security is threatened.

4.5.1 The Logistic Model estimation results

This analysis was included in the study to highlight the implication of marginal effects of climate variability on maize production by taking into consideration other factors said to influence the level of maize production. These factors are soil productivity and land ownership to farmers which were modelled by the logistic model equation (9)

$$\text{Log}\left[\frac{AHP}{1-AHP}\right] = \beta_0 + \beta_1 \log RFA + \beta_2 \log TMP + \beta_3 \log SOP + \beta_4 \log LOP$$

Where β_j is a vector of parameters that relate the explanatory variable Xi to the probability, the variables used in the model are:

AHP = Average harvest for maize farmers which is 1 if yes attained and 0 if otherwise

RFA = Rainfall amount to maize farming which is 1 if favorable and 0 if otherwise

TMP = Characterizes favorable temperature, yes =1 and 0 otherwise.

SOP = Soil potentiality to maize farming which is 1 if yes and 0 if otherwise

LOP = Characterizes land ownership of farmers, Land owning =1 and 0 otherwise.

The following table shows the estimated stata results of average maize harvest for farmers in Siha District.

Table 4.12 Binary Logistic Regression Model

Variables	Coefficients	Standard Errors	t-value	Sig
Constant	3.652	0.942	3.8768**	0.000
RFA	0.018	0.0026	2.8832	0.002
TMP	0.007	0.0173	2.5216	0.017
SOP	0.0231	0.0984	2.3571**	0.017
LOP	0.0649	0.2137	3.0469**	0.004

Source: STATA data Analysis, 2019, ** parameters significant at 5%

A logistic regression had 92 number of observations of farmers respondents LR Chi-square (3) = 24.63, Prob>Chi-square = 0.000 and the Pseudo R^2 = 0. 709. Using the Pseudo R^2, The logistic model explains 70.9% of the total variation in average maize harvest status of farmers (Table 4.18). The results indicated the coefficients of SOP, and LOP with the t-values of 2.3571and 3.0469 respectively were all found to be critical in explaining average maize harvest status among the sampled farmers. Soil potentiality is positive and significantly influencing maize production at a 5% level of probability. This implies that as the potentiality of the soil increases maize harvest also increases other factors remaining constant. This could be due to the fact that soil potentiality is generally productive whether through the application of natural or artificial fertilizers.

More specifically an additional chance of soil potentiality to maize farming increases the odds of (difference in probability) of producing maize harvest status by 7.7 %. And as the chance of making the soil more productive to farmers increases, the likelihood of raising the harvest of maize rises.

Land ownership is positive and critically affected maize harvest status of farmers at 5% level. This implies that an additional chance of land ownership to farmers increases the odds of (difference in probability) of producing maize harvest status by 3.5 %. And as the chance of owning land to farmers increases, the likelihood of raising the harvest of maize rises. This could be due to the fact that every person in the farming sector experiences the potentiality of lower production costs and farm management become more effective to farmers owning land compared to land leasing.

4.6 Summary of the chapter

Based on the results, it can be concluded that temperature has significantly increased over the 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.

CHAPTER FIVE

SUMMARY, CONCLUSSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter attempt to provide a summary of the results that were derived from the various analyses in the study. The conclusion is drawn from these results and the discussion in chapter 4 are also presented and finally some recommendations.

5.2 Summary of the main findings

This study was designed to assess the effects of climate variability on maize production in Siha District, Kilimanjaro Region. The focus of the study was over Siha District with special emphasis on Biriri and Olkolili wards **.**The data used in the study include Annual rainfall; mean a minimum and maximum temperature which was obtained from Kilimanjaro International Meteorological Agency (KIA). And the data for maize yields obtained from the farmers level and Department of Agriculture, Irrigation and Cooperatives at Siha District in Kilimanjaro as well as the literature review.

Methods used in the study include crop model to evaluate the impacts of climate change on crop production, the regression model was used to measure the relationship between climate variability and maize yields.

Understanding climatic variability on maize production is vital to policy making decisions to ensure food security in Siha district. Previous research has demonstrated the need for studies of maize production, and a wide variety of climatic variability estimates warrant a need for further research.

A time series regression model is used for patterns in the past movement of a variable and uses that movement to make an analysis of the behaviour of maize production in relation to climatic variability. In this analysis, it is tried to fit the best model for the seasonal maize production influenced by rainfall amount and temperature in Siha district. To trace the co- integration behaviour for maize production the latest available lag selection criteria such as AIC, SBIC, etc are used. Again, to select the fitted model, it is tried to fit the best simple model because the model contains fewer parameters to give a good model for analysis. To satisfy this condition, sometimes it was considered more than a 5% level of significance, and the model is able to explain practical weather situations on maize production.

For a logistic model, average household maize production is determined given the soil potentiality, while the average maize production is determined given the land ownership of a farmer. The model was estimated from the unique data set from the farmers in the Siha district with experience of farming for more than 5 years, both the presence of soil production potentiality and land ownership is recognized in determining maize production.

Regression model also indicated that temperature has significantly increased over the years and that rainfall has significantly declined. Increases in temperature could shorten the length of the growing season with temperature variation expected to have significant impacts on the agro ecological zones.

5.3 Conclusions

The purpose of this study was to research on impact of climate variability on maize production in Siha District, Tanzania. The study was guided by three research objectives, namely i) To examine the influence of temporal variability of rainfall on maize production in Siha district for the last 30 years ii) To examine the influence of seasonal variation of temperature on maize production in Siha district for the last 30 years and iii) To evaluate the marginal effects of temperature and rainfall on maize production in Siha District.

The impacts on maize production farmers to the study area are; shifting in agro-ecological zones, unpredictability in rainfall, increased weed competition and ecological changes for pests and diseases like invasion of fall armyworms, uncertainty in cropping patterns, reduced size of land for maize cultivation, food shortage as well as economic depression (poverty) due to higher investments with low return.

Maize farmers of Siha District have agricultural production which is closely connected to climatic variability that finds its central ground in temperature variations with respect to maize production. Food security challenges and problems cannot be solved apart from ensuring the environmental policy is directed to managing and containing the impacts of global warming and the like

The study found out that favourable rainfall amount would produce favourable maize produce in Siha district. Environmental policy that ensures rainfall related factors significantly affect food security in Siha district. In particular the study established that food security status is working against agricultural farmers as rainfall variability makes their expectations and plans be uncertain. The study also established that in Siha district there was high connection of maize production with soil productivity and land ownership to farmers. Furthermore, the study also established that in Siha district there was evidence of effects of short-term seasonal fluctuations in some years of climatic conditions which influenced maize production.

Furthermore, agricultural management policies which empower farmers to obtain high productivity should be emphasized. Farm extension officers should access maize farmers and train them and give technical expertise of making soil productivity high. Finally, farming subsidies should be strongly promoted and reach the targeted farmers to enable them increase the farming land size and obtain various needed inputs.

5.4 Recommendations

The main idea of this study was to examine the effects of climate variability on maize production and food security on maize farmers on Siha district. The implications of these findings were analysed and recommendations for practice, policy makers as well as for further researches were made.

5.4.1 Recommendation for Practice

Under this category, recommendations will be made to the government, development partners and the community.

(a) Government

For government to reduce the threats and risks of food insecurity must raise the maize crop production, must put in place strategies that will ensure climate variabilities that in most cases tend to be unpredictable to farmers properly managed. Other policy measures can be provision of subsidies, loans, and technical expertise incentives to maize farmers so that they can rely to commit their resources on maize crop rather than deciding to grow crops which do not conform to the soil and food security programmes, for example fertilizer subsidies, growing farms demos for famers to learn, and other good incentive conditions, that at least meet farmers’ expectations.

(b) Development partners

Committed development partners are needed to deal with maize production projects. Partners can note the challenges and design maize farming empowerment projects that may target the key productive wards in Siha district. These projects can engage youths who are potential labour resources that need employment and learning entrepreneurial skills in maize farming investment.

(c) The Community

There is a need for the community to get involved in reducing the unfavourable climate variability that generate floods and droughts in Siha District. The community should co-operate with the government and development partners to ensure that natural trees and vegetation is not destroyed through human activities.

5.5 Areas for further study

1. The present study did not cover all matters related to effects of climate variability on maize production and food security in Siha district of Kilimanjaro region. Therefore, the present researcher recommends the following for further researches; The study was carried out only in Kilimanjaro Region especially at Siha district. Therefore similar study needs to be conducted in other places to determine whether similar results are obtainable.

2. The study concentrated much on the climate variability affecting maize production. Therefore, a similar study needs to concentrate on the factors evolving around the maize production and then on climate variability to determine whether the findings would be similar.

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