ADAPTATION OF SMALLHOLDER MAIZE FARMERS TO TEMPERATURE AND RAINFALL VARIABILITY IN CAPRICORN DISTRICT MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA.

BY

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A RESEARCH THESIS SUBMITTED FOR THE DEGREE MASTER OF SCIENCE IN THE DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES, SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES, FACULTY OF SCIENCE AND AGRICULTURE, UNIVERSITY OF LIMPOPO (TURFLOOP), SOUTH AFRICA

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2019

DECLARATION

I, Kabelo Makadikwe Mazwi, declare that "ADAPTATION OF SMALLHOLDER MAIZE FARMERS TO TEMPERATURE AND RAINFALL VARIABILITY IN CAPRICORN DISTRICT MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA." is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

Supervisor: Mr D. Angwenyi
Co-Supervisor: Prof I.K Mariga

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Signature.............

ACKNOWLEDGEMENTS

Praise and thanks be to God for his loving-kindness and his endless mercy, favor and protection from the beginning of this research work to the end.

I am heartily thankful to my supervisor, Mr. D.Angwenyi, whose encouragement, guidance, constructive criticism and support, from the initial to the final phase, enabled me to develop an understanding of the subject. My sincere thanks also go to Professor I.K Mariga for supporting me all the way.

It is a pleasure to thank people of the Capricorn District Municipality who made this thesis possible i.e. the smallholder maize farmers; the Department of Agriculture and extension officers and South African Weather Service.

I also appreciate all the people who assisted me during the course of the research, like my mom, and sisters for their patience and understanding. I owe my deepest gratitude to my friend who was always there for me especially during the course of the research.

DEDICATION

I would like to dedicate this work to my beloved mother, Sarah Mazwi who has given me support in all years of my studies. To my grandmother - Christian Kekana, sisters and friend for their love, moral support and motivation throughout my studies.

ABSTRACT

Scientific evidence indicates that the earth's climate is changing rapidly owing to increase in greenhouse gas emissions. The increased concentration of greenhouse gases has raised the average temperature, altered the amount and distribution of rainfall globally and has increased floods and drought incidents (Belay *et al.*, 2017). These changes have affected smallholder farmers in developing countries, since they heavily depend on rainfed agriculture for their livelihood (Ndamani *et al.*, 2016). Smallholder farmers in South Africa faces a variety of risks associated with climate change, such as changes in rain patterns, increased evaporation rates, higher temperatures, increased pests and diseases and changes in diseases and pest distribution ranges and reduced yields. In carrying out adaptation measures to reduce the effects of climate variations on agricultural production, the smallholder farmers' encounters challenges or problems (Wilk *et al.*, 2012).

Based on this background, this research was conducted to (i) assess the trends in temperature and rainfall in Capricorn District Municipality between 1993 and 2013, (ii) assess the effects of changes in temperature and rainfall on smallholder maize farmers in Capricorn District Municipality and (iii) profile the smallholder maize farmers' adaptation strategies and the factors influencing the choice of adaptation method. Structured questionnaire was administered to 253 randomly selected smallholder maize farmers in Capricorn District Municipality. Descriptive statistics and multinomial logistic regression model were used to analyse the data. The statistical analysis of the climate data shows that temperature has increased over the years. Rainfall was characterized by large interannual variability, with the previous 20 years being very dry. Indeed, the analysis showed that farmers' observations were in line with the climatic data records. Smallholder maize farmers in the study area made attempts to adapt to temperature and rainfall by using practices such as change in planting season, mulching, weeding, crop rotation, and irrigation and conservation agricultural techniques. The results of the multinomial logit highlighted that gender, household size, farming experience, access to finance, farm income, access to climate information, access to extension are the main factors that enhance adaptive capacity. Any policy aimed at enhancing the adaptive capacity of the

farmers in the study area should thus consider making use the factors mentioned afore.

It was concluded that climate change in Capricorn District Municipality is a pressing problem which is beyond the capacity of the smallholder maize farmers to respond. Farmer's capacity to choose effectives adaptation option is influenced by householder demography. This implies that, there is a need to support indigenous adaptation strategies of the smallholder maize farmers with a wide range of institutional, policy and technology. Furthermore, providing credit, information and extension services farmers on climate change adaptation strategies and technologies, and investing in climate resilient projects like, improving on existing or building new infrastructure and building climate change monitoring and reporting stations will enhance their adaptive capacity.

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ABBREVIATIONS AND ACRONYMS

SAWS- South African Weather Service

IPCC- Intergovernmental Panel on Climate Change's

DAFF- Department Agriculture Forestry Fisheries

IDP- Industrial Development Plan

UNFCCC- United Nation Framework Convention on Climate Change

IPCC AR_1- Intergovernmental Panel on Climate Change First Assessment report

IPCC AR_2- Intergovernmental Panel on Climate Change Second Assessment report

IPCC AR_3- Intergovernmental Panel on Climate Third Assessment report

IPCC AR_4- Intergovernmental Panel on Climate Change Fourth Assessment report

IPCC AR_5- Intergovernmental Panel on Climate Change Fifth Assessment report

WWF- World Wide Fund

COP- Conference of the Parties

CMP- Conference of the Parties serving as the Meeting of Parties

AGBM- Ad Hoc Group on the Berlin Mandate

JI- Joint Implementation

WSSD- World Summit on Sustainable Development

AWG-LCA- Ad Hoc Working Group on Long-term Cooperative Action under the Convention

AWG-ADP -Ad Hoc Working Group for the Durban Platform for Enhanced Action

AWG-KP- Ad Hoc Working Group on Further Commitments for Annex Parties under the Kyoto Protocol

LULUCF- Land use, Land-use Change and Forestry

GCM- Global Circulation Model

IFPRI - International Food Policy Research Institute

UN- United Nation

FAO- Food and Agriculture Organisation

INDCs -Intended Nationally Determined Contributions

SECCP -Sustainable Energy and Climate Change Partnership

MNL-Multinomial logistic regression model

INDCs- Intended National Determined Contributions

C2ES- Centre for Climate and Energy Solution

(CMA1)-The first session of the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement

GHG- Greenhouse gases

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

According to Lasco *et al.* (2011), Earth's climate is changing. Since 1750, there has been an increase in the concentrations of greenhouse gases in the atmosphere resulting in global warming. The global surface temperature has increased by about 0.74 (0.56- 0.92°C) over the 20th century. Precipitation is highly variable and trends are more difficult to isolate, but the overall temperature and heavy precipitation events have increased in most regions, at the same time the occurrence of drought has also been on the rise, particularly since 1970 (IPCC, 2007).

Climate change has and is expected to affect smallholder farmers by exacerbating the risks they face. According to Etwire (2015), lack of rainfall resulted in droughts, leading to a reduction in soil moisture and a decline in crop yield. High temperatures may cause increased mortality of pollinators and affect populations of pests and diseases alter the type and number of pest and disease outbreaks. Increased temperatures may also favour the growth of weed species enabling them to compete more effectively with crop plants. Increase the frequency and severity of droughts and floods increase the likelihood of poor yields and crop failure (Harvey *et al.*, 2014).

1.2 PROBLEM STATEMENT

According to CSIR (2010), Limpopo Province got hotter and hotter between 1990 and 2010. At this period, the annual maximum temperature increased approximately by 0.5°C per annum. Besides increasing temperature, as presented in Figures 1.1 annual rainfall reduced drastically (SAWS, 2015). In addition, Benhin (2013) established that evaporation rates in the region increased and will continue to increase even further. Increasing temperatures, reducing rainfall and increasing evaporation has and is likely to increase demand for agricultural water. The changes that have taken place in the province are highly likely to be reflected in Capricorn District Municipality.

Since smallholder farmers have low adaptive capacity because of insufficient adaptive resources, there is a high likelihood they will be affected because they will not be able adapt well.

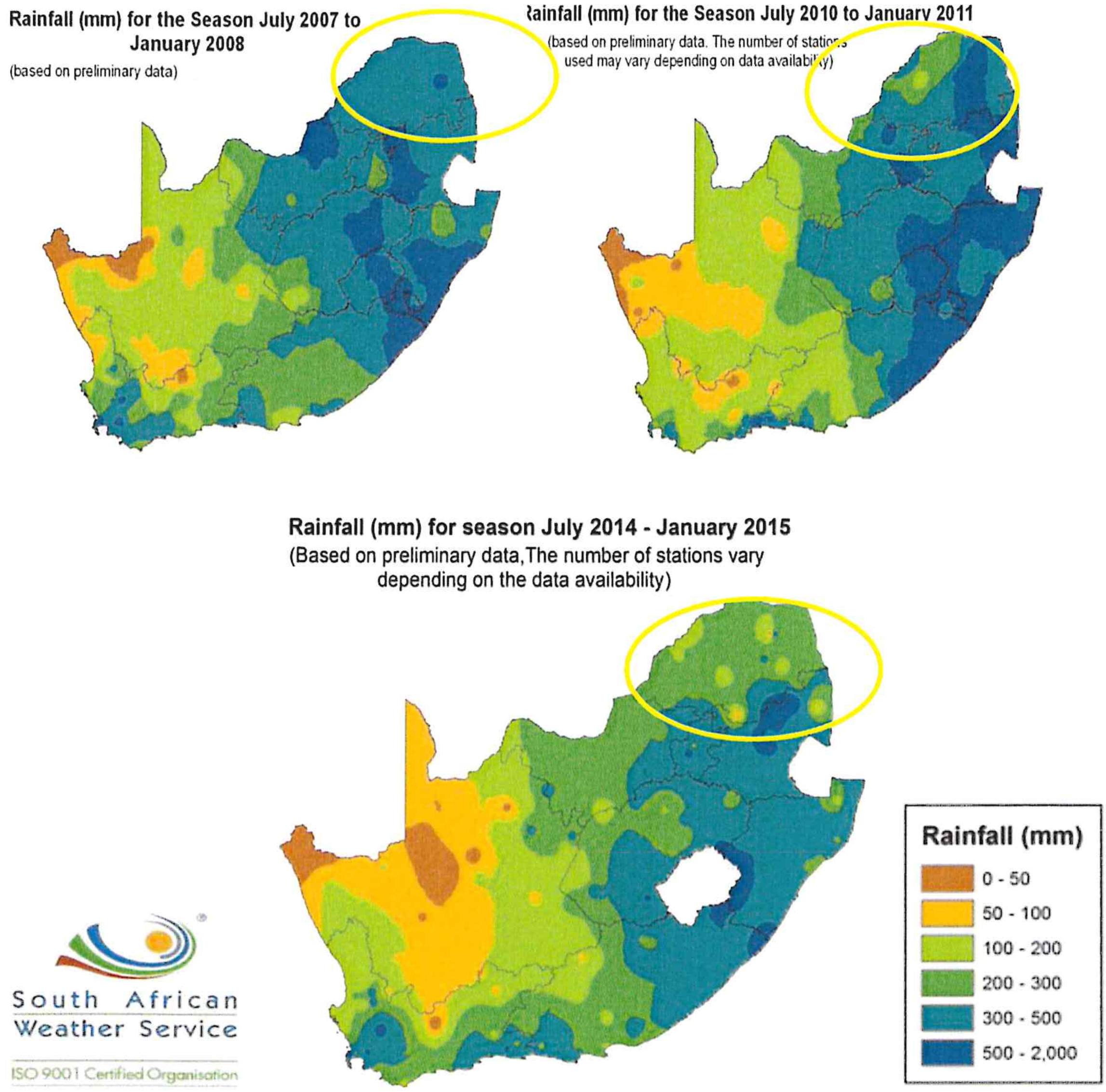

Figure 1.1: Rainfall for South Africa in mm for the season July 2007–January 2008 (top left), July 2010–January 2011 (top right), and July 2014–January 2015. (Source: SAWS, 2015)

1.3 AIMS AND OBJECTIVES

1.3.1 AIM

Assess the adaptation of smallholder farmers' to changing temperature and rainfall, assess factors influencing the choice of adaptation strategies as well as challenges hindering these farmers to adapt effectively in Capricorn District Municipality.

1.3.2 OBJECTIVES

I. Assess the trends in temperature and rainfall in Capricorn District Municipality between 1993 and 2013.

II. Assess the effects of changes in temperature and rainfall on smallholder maize farmers in Capricorn District Municipality.

III. Profile the smallholder maize farmers' adaptation strategies and the factors influencing the choice of adaptation method.

1.4 RESEARCH QUESTIONS

I. What were the trends in temperature and rainfall in Capricorn District Municipality between 1993 and 2013?

II. How have changes in temperature and rainfall affected smallholder maize farmers in Capricorn District Municipality?

III. How do smallholder maize farmers adapt to changes in temperature and rainfall and what are the factors influencing their choice of adaptation method?

1.5 DESCRIPTION OF THE STUDY

1.5.1 LOCATION AND SIZE

The study was carried out in Capricorn District Municipality, Limpopo Province, South Africa. Limpopo Province is located on the northern–most part of South Africa. It shares its borders with Mopani, Sekhukhune, Vhembe and Waterberg District Municipality (www.let.co.za). Capricorn District Municipality is one of the district municipalities in Limpopo Province and is comprise of five local municipalities -

Polokwane, Lepelle Nkumpi, Molemole, Blouberg and Aganang (Figure 1.4). Capricorn district municipality covers a total area of 185,222.27 ha which is 12% of the total area of Limpopo province (StatSa, 2011).

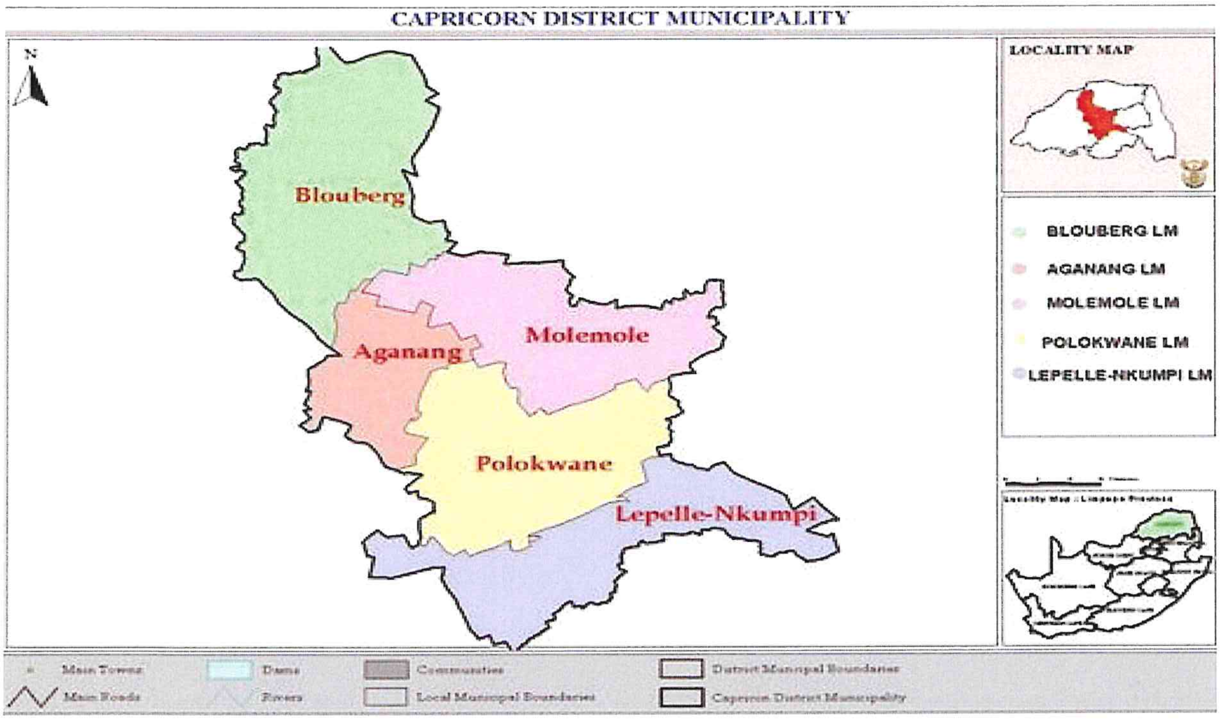

Figure 1.2: Location of Capricorn District Municipality (http//www.ldrt.gov.za)

1.5.2 CLIMATE

Capricorn District Municipality experience a warm temperature of 25°C in Summer and 10°C in Winter. The temperature is highest January and lowest in June. Capricorn District Municipality experiences summer rainfall between October and March, with the mean annual rainfall is 478 mm (IDP, 2013).

1.5.3 POPULATION

The 2011 national census found that the total population of Capricorn District Municipality was 1,261,463, with a population density of 58.1/km². Half the population Capricorn District Municipality reside in Polokwane Local Municipality. The other local municipalities' populations were as follows – Lepelle-Nkumpi Local Municipality 18%, Blouberg Local Municipality 13%, Aganang Local Municipality 10%, and Molemole Local Municipality 9%. Between 2001 and 2011 the municipality's annual population growth was 0.8% (Capricorn District Municipality, 2015).

Approximately 30.53% of all the settlements including towns and villages in the Capricorn District Municipality area are located within Polokwane Local Municipality. Approximately 20% of all the larger settlements with 5 000 people and more are also located within this local municipal area. All five local municipal areas have a large number of small villages, that is, villages with less than 1000 people (IDP, 2013).

1.5.4 AGRICULTURE

The Limpopo Department of Agriculture is a key partner of the district's agriculture development programme. More than 100 different agriculture development projects are being supported across the district. These are focused on poultry, vegetables, lucerne production, livestock, dairy farming and agro-processing (Statistics South Africa, 2012).

The Capricorn District Municipality is home to one of the largest citrus estates in the country, namely, Zebediela Citrus Estate (13 785 ha) which is located in the Lepelle-Nkumpi Municipality in Zebediela. The Zebediela Citrus Plantation exports most of its produce and supplies to local market. Potatoes are the most produced and important crop in the Capricorn District Municipality. Followed by tomatoes, eggs, broilers and beef. Pork and citrus production are also substantial (Statistics South Africa, 2012).

Capricorn District Municipality has thriving livestock farming. The majority of livestock are goats (44%) followed by cattle (38%), pigs (10% and sheep (9%). Commercial livestock farming constitutes 25% of livestock farming whilst communal represents 75% (Statistics South Africa, 2012).

1.6 SCOPE OF THE STUDY

The study was carried out in Capricorn District Municipality, Limpopo province, South Africa. It is comprised of 5 local municipality being Polokwane, Lepelle-Nkumpi, Aganang, Molemole and Blouberg local municipality. The aim of this study assess the adaptation of smallholder farmers' to changing temperature and rainfall, assess factors influencing the choice of adaptation strategies as well as challenges hindering these farmers to adapt effectively in Capricorn District Municipality. This study includes (i) assess the trends in temperature and rainfall in Capricorn District Municipality between 1993 and 2013, (ii)assess the effects of changes in temperature and rainfall on smallholder maize farmers in Capricorn District Municipality and (iii) profile the smallholder maize farmers' adaptation strategies and the factors influencing the choice of adaptation method.

1.7 JUSTIFICATION OF THE STUDY

Small holder farmers play an important role in household food security amongst the rural poor. Smallholder agriculture play a key role in improving dietary patterns, both for smallholder farmers themselves and for urban populations. Smallholder agriculture plays a major role in the national economy of many countries, particularly in least developed countries by increasing their Gross Domestic Product, increasing employment opportunities and the creating new markets by directly linking producers with consumers.

However, smallholder farmers are vulnerable to temperature and rainfall changes because of their low adaptive capacity, they use simple production systems and outdated technology. Because of this, smallholder farmers have low returns and high levels of labour fluctuation (DAFF, 2012). Lack or less climate information, lack of access to formal safety nets, lack of or insufficient finance, lack of or insufficient basic services, institutional support lead to insufficient production (Schaeffer *et al.*, 2013). Temperature and rainfall are the main drivers of agricultural production. Understanding the relationship between impacts of temperature and rainfall changes and adaptations is important to enhance small holder farmer's resilience. Therefore, there is a need to develop and identify the approaches to strengthen the adaptive capacity of smallholder farmers and enhance their ability to respond to climate change and variability.

1.8 STRUCTURE OF THE DISSERTATION

The rest of the dissertation is organized as follows:

Chapter 1: Presents introduction, problem statement, aim and objectives and the description of the study.

Chapter 2: Presents the background to climate change, the impacts of climate change on crop production, adaptation strategies to climate change by farmers, determinants of adaptation strategies to climate change by farmers, challenges faced by farmers in adapting to the impact climate change.

Chapter 3: Discusses methods and data used in the study.

Chapter 4: Presents changes in temperature and rainfall and their effects on smallholder maize in Capricorn District Municipality.

Chapter 5: Presents a discussion on smallholder maize farmers' adaptation to changes in temperature and rainfall and the factors influencing smallholder maize farmer's choice of adaptation method(s).

Chapter 6: Presents the summary of findings, conclusion and outlines recommendations for policy implication improvement

1.9 DEFINITION OF TERMS AND CONCEPT

Adaptation: the action people take in response to, or in anticipation of, projected or actual changes in climate to reduce adverse impacts or take of the opportunities posed by climate change (Deressa *et al.*, 2009).

Climate: the average pattern of weather over the long term (CSIR, 2005)

Adaptation strategies: adjustment to ecological, social or economic system in response to observed or expected changes in climatic stimuli and their effects and impact (Schaeffer *et al.*, 2013)

Smallholder farmers: those farmers owning small-based plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour (DAFF, 2012)

Climate change: statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer) (BFAP report, 2007 coting IPCC, 2007)

Climate variability: variations in the prevailing state of the climate on al temporal and spatial scales beyond that of individual weather events (CSIR, 2005).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Earth's climate is changing. Since 1750, there has been an increase in the concentrations of greenhouse gases in the atmosphere resulting in global warming (Lasco *et al.,* 2011). According to IPCC (2007), the global-average surface temperature has increased by about 0.74°C over the 20th century. Precipitation is highly variable and trends are more difficult to isolate, but overall precipitation and heavy precipitation events have increased in most regions, at the same time the occurrence of drought has also been on the rise, particularly since 1970 (IPCC, 2007).

Climate change has and is expected to affect smallholder farmers by exacerbating the risks they face. Etwire *et al.* (2013) argued that increasing rainfall variability results in droughts leads to reduction in soil moisture ultimately causing to a decline in crop yield. According to Adams *et al.* (1998), large areas of Latin America are affected by extreme events such as heavy rainfall leading to floods which resulted in reduced crop yield of between 10% and 30%. High temperatures cause increased mortality of pollinators as well affecting populations of pests and diseases by altering the type and number of pest and disease outbreaks. In 2003, when the temperature was 6°C above long-term means, maize yield dropped by 36% in Italy (FAO, 2008; citing IPCC, 2007). In Philippines, higher evapotranspiration rates due to higher temperature resulted in increasing demand for water for irrigation (Schaeffer *et al.*, 2013). A rise in temperature of 0.8 °C in the Corn Belt Washington, DC decreases corn yields by 2% to 3% and 8.3% decrease in corn yield per each 1°C increase in average growing season temperature (Walthall *et al.*, 2012). A tropical storm in Jamaica resulted in significant damage on agricultural infrastructure, which indirectly affected agricultural production because farmers could not access agricultural inputs (Lasco *et al.*, 2011). Increased temperature in California resulted in increasing number and types of pests and lengthened pests' breeding season (Adams *et al.,* 1998). Droughts and floods in Swaziland led to reduction in maize production (Oseni *et al.*, 2011). A study by Akpalu *et al.* (2009) in South Africa has revealed that a 10%

reduction in mean precipitation reduced maize yields by approximately 4%. However, heavy rainfall led to maize diminished yields. In the same study, mean temperature increase from 21.4°C to 21.6 °C caused maize yields to increase by 0.4% and beyond this range, yields of maize diminished.

Farmers need to use adaptation practice in order to cope with the effects of climate change. Studies have shown that without better adaptation to climate change, farmers will become more vulnerable and agriculture becomes severely affected. Adaptation lessens adverse effects and takes advantage of benefits of changes in climate variables. In Florida, farmers respond to weed, insects and pathogens through the use of herbicides, insecticides and fungicides (Karl, 2009). In China, farmers claimed that they use composting and mulching to conserve moisture and improve soil fertility so as to increase the crop production (Wang *et al.*, 2010). The study by Ndamani *et al.* (2016) in Ghana indicated that farmers use drought tolerant, early maturing and change in planting date to adapt to dry spells, drought and floods. South African farmers generally use fishnets, grass, and plastic as covering to protect their plants against dryness and heat, cold and frost (Benhin, 2004). In eMcitsheni- Kwazulu Natal farmers introduced short-maturing varieties of maize in an attempt to respond to declining rainfall at the end of the growing season (Thomas *et al.*, 2007).

Although, diverse climate change adaptation strategies exist, but farmers were not practicing them to their full potential due to constraints. For example, the study in United State indicated that lacks of financial resource prevented smallholder farmers in from accessing crop varieties that tolerate heat and drought conditions (Karl, 2009). Lack of money to purchase farm inputs, such as hybrid seeds, fertilizers and farm implements, was perceived as an important barrier to farmers (Van *et al.*, 2015). Rural areas have a much harder time accessing credit because banks encounter higher financial costs and constraints in these areas due to rural locations and related risks (Deininger *et al.*, 2007). The study by Belay *et al.* (2017) indicated that shortage of farmlands has been associated with the limited capacity of farmers to intensify their agricultural production. Lack of storage weakens the bargaining power of the smallholder farmers when it comes to negotiating the price of farm produce. So many of farmers cannot store their produce and therefore accept whatever price they are offered (FAO, 2001). Farmers with limited extension services asserted that the information provided is not helpful and not relevant to mitigate the effects of climate change (Benhin, 2004).

In this chapter presents details on the history of climate change, impacts of climate change on crop production, climate change adaptation strategies in crop production and factors influencing the choice of adaptation strategies. It also highlights the challenges faced by smallholder in adapting to impacts of climate change.

2.2 IMPACTS OF TEMPERATURE AND RAINFALL VARIABILITY ON CROP PRODUCTION

Climate change aggravates the negative impact on crop yield. In 2003, when the temperature was 6°C above long-term means, maize yield dropped by 36% in Italy (FAO, 2008; citing IPCC, 2007). A rise in temperature of 0.8 °C in the Corn Belt Washington, DC decreases corn yields by 2% to 3% and 8.3% decrease in corn yield per each 1°C increase in average growing season temperature (Walthall *et al.*, 2012). A tropical storm in Jamaica resulted in significant damage on agricultural infrastructure, which indirectly affected agricultural production because farmers could not access agricultural inputs (Lasco *et al.*, 2011). In the Philippines, higher evapotranspiration rates due to higher temperature resulted in increasing demand for water for irrigation (Schaeffer *et al.*, 2013). The empirical study in Ghana showed that increasing temperature resulted in the decline in crop yield (Ndamani *et al.*, 2016) Droughts and floods in Swaziland led to reduction in maize production (Oseni *et al.*, 2011). A study by Akpalu *et al.* *(*2009) in South Africa has revealed that a 10% reduction in mean precipitation reduced maize yields by approximately 4%. However, heavy rainfall led to maize diminished yields. In the same study, mean temperature increase from 21.4°C to 21.6 °C caused maize yields to increase by 0.4% and beyond this range, yields of maize diminished.

In the USA, increase in rainfall led to increase in humidity resulting in the development of fungal disease, insects and disease-causing vector on crop plants. Modelling responses of both pathogens and insect vectors to changing precipitation is complex, but there is cause for concern over possible spread of major diseases that attack smallholder crops (Morton, 2007). Rainfall affects growth and survival principally through increased cloud cover, which reduce activity and changes the nutritional quality of the plants upon which insects feed. Humidity influences the prevalence of insect diseases, as well as plant diseases that insects carry. The study by Morton (2007) conducted in United Kingdom, found that Maize Streak Virus and Cassava Mosaic Virus are found in areas where rainfall increases, and sorghum head smut (fungal disease) in areas where rainfall decreases. Droughts, followed by intense rain in Des Moines, in the heart of the U.S. Corn Belt reduced soil water absorption and increased the potential for flooding, thereby creating conditions favouring fungal infestations of leaf, root and tuber crops in runoff area (Tropical Agricultural Association, 2010). Farmers in Philippines reported a number of climate change abnormalities such as pests and diseases in rice, corn and fruits trees due to excessive rainfall. Fruits trees are affected by heavy rainfall where there was flower abortion, failed fruits and attack of scale insects and aphids (Lasco *et al.,* 2011*)*. Continued climate change alters the abundance and types of many pests, lengthen pests' breeding season, and increase pathogen growth rates (Anderson *et al.*, 2006). Deressa *et al.* (2005) in the study conducted in South Africa found that the negative relationship between increased precipitation and crops due to the possible outbreak of pests and insects are depressed under low precipitation but start reproducing when precipitation increases (Deressa *et al.*, 2005).

Temperature variability is the boundaries for crop growth. Higher temperatures adversely affect plant growth, pollination, and reproductive processes. However, as temperatures rise beyond the optimum, instead of falling at a rate commensurate with the temperature increase, crop yield losses accelerate. For example, a study by Schlenker and Roberts (2009) conducted in United State indicated that yield growth for corn, soybean, and cotton gradually increases with temperatures up to 29˚C to 32˚C and then decreases sharply as temperature increases beyond this point. Another study by Lobell *et al.* (2011) on nonlinear heat on African Maize showed a yield decline between 3.8% and 5%.

The effects of rising temperature depend upon current mean temperatures during critical reproductive growth phases (Hertel *et al.*, 2010). At middle and higher latitudes of Europe, global warming has extend the length of the potential growing season, allowing earlier planting of crops in the spring and earlier maturation and harvesting (Olesen *et al.,* 2002). It has shown that from sowing to crop maturity, the crop growth was reduced due to warmer temperature. Maize maturity reached 17 days earlier in Zamorano and 11 days earlier in Comayagua and la Esperanza. In future it is predicted to a reduction of 3 to 20 days from sowing to crop maturity (Diaz-Ambrona *et al.*, 2013). A rise in temperature of 0.8 °C in the Corn Belt decreases corn yields by 2% to 3% and 8.3% decrease in corn yield per each 1°C increase in average growing season temperature. For soybean, the mean growing-season temperature in the upper Midwest is approximately 22.5°C, so a 0.8°C increases in temperature increases yields. For the Southern United States, growing-season temperatures are higher, such as 0.8°C is estimated to decrease yields by approximately 2.4% (Walthall *et al.*, 2012).

Climate change can affect agriculture in a variety of ways. For example, beyond a certain range of temperatures, any increase in temperature tends to lose soil moisture and reduce yields because crops speed through their development, producing less grain in the process (Cline, 2008). According to Cresser *et al.* (2008), high temperature has resulted in reduced soil moisture in many areas of tropical and mid-continental regions. This has further led to reduced available water for irrigation hence impairing crop growth. Phillippines has experienced a declining production of rice and wheat due to heat and water stress (Cresser *et al.*, 2008). The study by Olesen *et al.* (2002) showed that the rice yield declined by 10% for every 1 °C increases in temperature. Besides the effect on soil moisture, the demand for water for irrigation has increased due to warmer climate (Olesen *et al.,* 2002). Higher temperatures in the South western Zimbabwe interfered with the ability of plants to get and use moisture because evaporation from the soil accelerates when temperatures rises and plants lose more moisture from their leaves (Cline, 2008).

A relatively immediate way in which crop production may be affected by climate change is through elevated temperatures. For example, an increase of mean temperature between 1°C and 3°C benefit crop in temperate regions while in tropical and seasonally dry regions have negative impacts particularly cereal crops (FAO, 2008). The optimal temperature for wheat is between approximately 15°C and 20°C, depending on variety, annual average temperatures during the crop growing period in Sub-Saharan Africa already exceed this range. With maize being the most produced crop in Africa and being sensitive to temperatures above 30°C during the growing season, yields diminished by 1% for each day a maize crop above the threshold and similar thresholds have been observed in soybeans and cotton (Schaeffer *et al.,* 2013).A very widely produced crop in Africa, maize, is particularly sensitive to temperatures above 30°C during the growing season and yields diminished by 1% for each day a maize crop is subjected to temperatures above this threshold(Lobell *et al.*, 2011).

Warming increases the occurrence of weeds. The continued warming resulted in the northwards expansion of invasive species and weeds. Weeds compete with crops for soil nutrients, light, and space. Drought conditions increase the competition for soil moisture; humid conditions increase the proliferation of weeds; and warmer temperatures increase the maximum biomass of grass weeds. Southern farmers lose more crops to weeds than northern farmers in United State (Rosenzweig *et al.*, 2001). In United State, southern farmers lost 64% of the soybeans crop to weed while the northern farmers' loss 22% (Karl, 2009). The soybean and corn losses in the southern Gulf States are associated with a number of very aggressive weed species found in tropical areas (e.g., prickly sida and Johnson grass). Warmer temperatures and an increase in the number of frost-free days, allows a northward expansion of aggressive weeds into other areas of the Midwest, with subsequent effects on maize and soybean production (Olesen *et al.,* 2002).

Pest outbreaks are associated with dry years, although extreme drought is unfavourable to insects. Exposure of fruit to drought condition and temperature extremes approaching 40 °C induced metabolic disorders and facilitate fungal and bacterial invasion. Heat injury and disease incidence are easily observed at the end of storage (Moretti *el at.*, 2010). The 1988 drought in the U.S. Midwest, accompanied by higher than normal temperatures, affected crop pests' outbreaks of two-spotted spider mites damaging soybeans throughout the entire Midwest region. The damage occurred during the critical flowering, pod-development and pod-filling growth stages and estimated losses to Ohio farmers were $15 to 20 million (Rosenzweig *et al.*, 2001). Under changing climate, environmental thresholds currently keeping some pests in check may be exceeded because of increased variability, making pest outbreaks to become more common as a result of increased climate variability (Ndambiri *et al.*, 2013).

The occurrence of extreme climate variability such as prolonged dry period and low rainfall spell coinciding with the critical stages of crop growth and development led to significantly reduced crop yields and extensive crop losses. The intermittent rainfall associated with drought limited the production of maize in the Guinea Savanna of West Africa were by 80% of the maize famers suffered periodic yield reduction due to drought stress. This was because drought at flowering and grain filling period caused loss of 40-90% yield (Ammani *et al.*, 2012). The study by Oseni *et al.* (2011) conducted in Swaziland found out that maize production was on steady decline due to erratic rainfall variability and the area planted to maize has also been reduced to adapt to the anticipated drought period (Oseni *et al.*, .2011).

The impact in warming increases the risk of plant to frost damage. Mild winter accompanies by early spring occurs more frequently as climate warms up resulting in premature plant development and blooming causing an exposure vulnerability to young plants to seasonal frost. In United State, the 2007 spring freeze caused a widespread devastation of crops as frost occurred during flowering period and early development of wheat (Walthall *et al.*, 2012). In Rocky Mountain where reduced snow cover leaved young plants unprotected to spring frost which led to low yield (Karl, 2009).

Precipitation has a direct influence on agriculture. Changes of the timing, intensity, and amount of rain/snow mix for a location increases the management challenge of delivering water to crops. For example, excessive water during corn's early growth stages caused a reduction in growth and even death, while soil water deficit led to less growth and lower yields when the stress occurs during the grain filling period of growth (Walthall *et al.*, 2012). Waterlogging reduced wheat yields 20% to 50%, and prolonged flooding killed wheat crop. Untimely rains delay plantings and harvests, and rains prior to harvest caused pre-harvest sprouting, which lowers yield but more importantly, reduces grain quality (Collaku and Harrison 2002).

Climate variability has a negative impact on crop yield. According to Gbetibouo (2009), the negative impact of climate change on crop yield was pronounced in Africa. Precipitation and temperature are found to have opposite effects on yield levels and variability of corn (maize). Furthermore, more rainfall caused yield levels to rise, while decreasing yield variance and that temperature has a reverse effect on maize production (Gbetibouo, 2009). Lobell *et al.* (2011) emphasised that Africa faced a 30% decline in maize production because rainfall and temperature in Africa are changing quite fast.

Heavy rainfall and associated floods result in the destruction of agricultural farm, produce and equipment. Heavy rainfall has caused the destruction of physical infrastructure sustained significant damage for agriculture equipment and destructions including farm building, farm roads and irrigation equipment. High rainfall often caused severe damage to land resulting in soil erosion where by a total area of 739.6-kilometre farm roads were damaged by heavy rainfall and Tropical Storm Nicole in 2011 in Jamaica. The 24-hour rainfall during hurricane Ivan in Jamaica exceeded 100 years return period rainfall period amount in area including Rose Hill and Hartham has resulted in the erosion of all agricultural resources and infrastructure (FAO, 2013).

There have been incidences where climate change has impacted on agricultural production. The increase in the incidence climate extreme such as floods, droughts and tropical cyclone resulted in the extensive damage of property in Metro Manila, Philippines (Lasco *et al.,* 2011*)*. According to Ramirez *et al.* (2012), Belize was strongly affected by Hurricane Keith of 2002 in Beliza, which caused material losses as well as serious damage to infrastructure on the agricultural sector. Furthermore, small producers who do not have any kind of insurance against hazards and are the ones who suffer the greatest negative effects of natural dangers (Ramirez *et al.*, 2012).

Akpalu *et al.* (2008) found that a 10% reduction in mean precipitation in South Africa reduced the mean maize yield by 4%. The drought diversification in parts of South Africa in 2015 made the country's farmers lose up to R10 billion in revenue. The worst affected areas were Kwazulu-Natal, Free State, Limpopo, North West and Northern Cape where by farmers grew white and yellow maize. The 2015 maize harvest was estimated to be worst in eight years (City Press, 2015).

2.3 TEMPERATURE AND RAINFALL VARIABILITY ADAPTATIONS TO CROP PRODUCTION

According to Ngigi (2009), adaptation to climate change and variability necessitates the adjustment of a system to moderate the impacts of climate change take advantage of new opportunities, and cope with associated consequences. Deressa *et al.* (2009) said that adaptation reduces the negative impact of climate change. Adaptations in agriculture vary depending on the climatic stimuli to which adjustments are made, different farm types and locations, and the economic, political and institutional conditions (Reidma *et al.*, 2010). These adaptation strategies were mainly autonomous adaptations where farmers changed their livelihoods in response to changing climate. These kinds of adaptations are based on accumulated knowledge and experiences over the years by the residents. These results corroborate findings by Boko *et al.* (2007) who noted that strategies of adaptation already observed in Africa include the use of drought tolerant and early maturing varieties and change of planting dates to adapt to drought and floods. Benedicta *et al.* (2010), the main adaptation strategies of farmers in Sekyedumase District in Ghana include change in crop types, planting short season varieties, changing planting dates and crop diversification to crop loss and drought condition. According to Sekaleli and Sebusi (2013), added that some of the farmer's adaptation strategies in Lesotho include use of keyhole and trench gardens and application of traditional medicine to control pests and diseases

According to Lasco *et al.* (2011), the change in cropping calendar is one of the adaptation strategies that farmers use to adapt to climate change. It involves altering the timing of farm activity to suit the climatic variation. In upland farms of Pantabangan, Nueva Ecija in the Philippines farmers adopted to the early onset of rainy season through early cultivation in order to maximise productivity and yields. This has resulted in high production. The author continued to say that some farmers have planted different crops in order to ensure a harvest of one crop at different times (Lasco *et al.*, 2011).

The change in rainfall distribution and amount resulted in most of the farmers planting crops with shorter growing period. Seasonal and semi-permanent farmers in Viet Nam have adopted short growing rice. The use of short-cycle rice allowed farmers to produce two cycle of rainfed rice within seven months of rainy season in the Mekong River delta (Lasco *et al.,* 2011). In Mali farmers responded to shorter rainy season by using short cycle varieties of sorghum (Mertz *et al.*, 2009). According to Jauna *et al.* (2013), said most crop farmers in sub-Sahara Africa where flooding occurs frequently have planted short duration crops to avoid crops growing and harvesting during the intensive rainfall period. Planting crops with shorter growing period such as cabbage, maize and rice has also been used to adapt to climate change (Benhin, 2004). In eMcitsheni, Kwazulu Natal. farmers introduced short-maturing varieties of maize in an attempt to respond to declining rainfall at the end of the growing season (Thomas *et al.*, 2007). In Mantsie, North West responded to the shortening of the rainy season by the occasional use of winter maize and by trialling quick maturing crop varieties using seeds bought in nearby towns (Thomas *et al.*, 2007).

Changes in climate have resulted in heavy rainfall, heat and frost. In some instances, South African farmers generally use fishnets, grass, and plastic as covering to protect their plants against dryness and heat, cold and frost (Benhin, 2004). The study by Morton (2007) in USA concluded for some better chance of some crops to survive, multiple crops were grown instead of one due to unexpected frost hit and flooding. According to Maponya *et al.* (2012), farmers in Limpopo Province also put nets around their crops to protect against colds, heat and frost. Tyre burning is also popular among resource poor farmers to protect their crops against cold. The burning of tyres serves as a blanket for crops like tomatoes during cold season. Reducing of planting space is also used by some resource poor farmers against cold weather. This is used mostly by cabbage and spinach farmers, who believe that by reducing planting space, crops serve as blanket to each other during cold weather and this method is working very well (Maponya *et al.*, 2012).

Higher temperature resulted in the increase of evapotranspiration and loss of soil moisture. Ngigi (2009) added that the soil moisture improvement techniques such as Zai (application of compost), semi-moons and mulching was also used which are practiced in northern Ghana, Burkina Faso and Mali as adaptation strategies to prevent moisture. Farmers in South Africa have resorted to increase the application of chemicals such Erian to reduce evapotranspiration. They also apply more manure to keep the moisture content of the soil higher and retain the soil fertility (Benhin, 2004). Some of the farmers have used mulching such as layers of muck, peat, compost and plastics and grass to cover the land to preserve soil moisture, cool the soil surface and stabilize soil temperature (Thomas *et al.*, 2007).

Due to the increase in the occurrences of drought, farmers have adopted to several strategies. According to Jauna *et al.* (2013), due to occurrence of extreme events such as drought and floods most farmers in sub-Sahara Africa have switched to planting high water-requirement crops and low water-requirement crops. According to Ngigi (2009), farmers in Nigeria, Senegal, Burkina Faso and Ghana have used drought-resistant crop varieties to adapt to drought (Juana *et al.*, 2013). The study by Belay *et al.* (2017) in Ethiopia added that due to drought, crops like barley, peas and beans were performing poorly and some farms has reduced the portion of land for crops. The author continued that in some cases farmers stopped their production and some have opted to grow other crops. Another study by Temesgen *et al.* (2014) in Ethiopia added that the repeated drought in the area resulted in the tendency of intensively using irrigation in their farming system (Temesgen *et al.*, 2014). Farmers were also practicing irrigating farming from small rivers and underground water (Belay *et al.*, 2017). Some farmers in South Africa have shifted from flood irrigation to sprinklers irrigation for the wise use of water (Benhin, 2004).

Faced with climate change and the prospect of increasing water scarcity, farmers have already shown a willingness to plant crop varieties with better resilience to adverse weather. The study by Wang *et al.* (2010) found that 42% of villages farmers in China have adapted to water saving technologies such as plastic sheeting, drought resistant varieties, retaining stubble/employing low-till methods, and surface level plastic irrigation pipe. Farmers in Cang County in Hebei province selected drought-resistance crop varieties (including new varieties for wheat, cotton and maize) in response to decreased water availability (Wang *et al.*, 2010). According to the study by African Technology Policy Studies Network (ATPS) 2013, drought prone areas in Lesotho, farmers use roof water harvesting technology to collect water and store it in stone built-tanks next to their houses and this is used for watering crops in the garden as well as for household use. The smallholder farmers in South Africa have built their own boreholes and small dams to conserve water. About 60% of the farmers in South Africa choose irrigation as an option to adjust to climate changes (Benhin, 2004).

Changes in climate had resulted in the increase of the occurrence of pests, disease and pathogens. In Finland, the use of pesticides kept low through the adoption of integrated pest management systems, which targets the control measures to the observed problem (Olesen *et al.,* 2002). Higher temperature and drought caused the increase of pests such spider mites in U.S. Midwest. Approximately 3.2 million hectares were sprayed with insecticides to control the mites across the region (Rosenzweig *et al.*, 2001). Due to the increase in the presence of pests, spraying is already much common in warmer areas than cooler area. In Florida, sweet corn growers spray their fields 15 to 32 times a year to fight pests. The farmers in Florida respond to weed, insects and pathogens through the use of herbicides, insecticides and fungicides (Karl, 2009). According to Lasco *et al.* (2011), order to maintain general hygiene around the villages and garden, most of farmer in Philippines have kept irrigation canal width of less than 30 cm to prevent rat nesting. These measures were supplemented by the installation of a plastic fence with built-in traps. At night the rats follow the line of the plastic until they reach a hole which they enter to reach the crops. The rats are often caught and removed the following morning. The results have resulted in 50% reduction in the use of chemical rodenticides (Lasco *et al.*, 2011). According to Maponya *et al.* (2012), multi cropping and crop rotation was implemented by famers in Mafeteng district reduce the risk of total loss from pests.

Heavy rainfall resulted in the loss of soil fertility. Severe erosion caused an increase in runoff of fertile soil and leaching of agricultural nutrients. According to the study by FAO (2007) in Rome on the adaptation to climate change in agriculture, forestry and fisheries concluded that the key element to increase the soil fertility is to improve soil organic matter. And can be done by stabilizing the soil structure so that soil absorbs enough amount of water required. The study by Enete *et al.* (2011) conducted in Nigeria added that high fertilizer application is therefore expected as an adaptation practice in order to maintain soil fertility. African Technology Policy Studies Network (2013) further added that farmers with livestock, especially cattle, use cow-dung instead of inorganic fertilizers when they plan to add fertility to the soil.

2.4 FACTORS INFLUENCING THE CHOICE OF ADAPTATION STRATEGIES

According to Deressa *et al.* (2009), farmers' response to climate change or their choice of adaptation methods are influenced by their socio-economic and institutional factors. Socio-economic factors like gender, age, educational level of household head, total farm size, ownership of radio and income from crop sale all influence adaptation option. Institutional factors like the presence of a market, access to formal agricultural extension, farmer-to-farmer extension and credit from family and friends also have a bearing on what options farmers employ to adapt to climate change. The authors continued that knowledge of these factors assist policy makers to strengthen adaptations by investing on them. According to Yesuf *et al.* (2008), Nhemachena and Hassan (2007) and Gbetibouo (2009), farmers' adaptation of climate change adaptation strategies is influenced by frequent and more accurate climate information from meteorological centres, formal and informal institutions, access to credit and extension information, amount of seasonal rainfall, geographical location, household size, age and literacy of household head.

Deressa *et al.* (2009) found that age is significantly and negatively related to farmer's decisions to adopt in soil and water conservation programs. According to Nhemachema *et al.* (2008) old farmers have with more experience and adapt to changes in climate than young farmers. However, young farmers have a longer planning horizon and to take up long-term adaptation measure. However, a study by Tazeze *et al.* (2012) conducted in Ethiopia argued that age of the household head increases, the person is expected to acquire more experience in weather forecasting and that helps increase in likelihood of practicing different adaptation strategies to climate change. A study by Gbetibouo *et al.* (2009) indicated a negative relationship between age and adoption of improved soil conservation practices, which suggests that older farmers may be less willing to take the risks associated with new farming practices and technologies

Experience in farming increases the probability of uptake of adaptation measures to climate change Deressa *et al.* (2009). Studies indicated that experienced farmers have a higher probability of perceiving climate change as they are exposed to past and present climatic conditions over the longer perspective of their life span (Apata, 2011). The study Van *et al.* (2015) in the study conducted in Northern Central Coast of Vietnam found that farming experience was found to account for increasing the likelihood of taking up adaptation strategies because experienced farmers have more knowledge about changes in climatic elements, and on best agricultural practices to adopt. Another study by Abid *et al.* (2015) found that years of farming experience significantly increases the probability of choosing changing crop varieties, changing planting dates and changing fertilizer as adaptation measures. Therefore, it can be concluded that farmers with greater farming experience are more aware of past climate events and better judge how to adapt their farming to extreme weather events.

According to Tazeze *et al.* (2012), citing Deressa *et al.* (2009) farm income of the households has a positive and significant impact on conserving soil, using different crop varieties, and changing planting dates. The authors found that nonfarm income has a negative relationship with the adaptation of soil conservation practices and the use of different crop varieties, although these results are not statistically significant. Uddin *et al.* (2014) in a study conducted in Bangladesh added that farmers with high income adapt to climate change and variability than farmers with lower incomes. The off-farm livelihoods activities of farmers diversify and supplement income. On the other hand, remittances and off-farm jobs might also be another source of annual family income of the farmers. Further, Nhemachena and Hassan (2007) indicated that per capita income has a positive influence on farmers' decisions to take-up adaptation measures. The study by Ndambiri *et al.* (2013) in the study conducted in Kenya to evaluation of farmers' perceptions of and adaptation to the effects of climate change found that farmers' income has a positive relationship with the uptake of farming technologies since any adoption adaptation process requires that the farmer has sufficient financial wellbeing. Gbetibouo (2009) explained that wealthier farmers are more interested to adapt by changing planting practices, using irrigation, and altering the amount of land farmed.

Gender is an important variable affecting adoption decision at the farm level. Female farmers are more likely to adopt natural resource management and conservation practices (Nhemachema *et al.*, 2008). According to Shongwe *et al.* (2014), female headed households are more likely to take up adaptation options since most of rural farming is done by women, while men are employed in towns, cities and mines. Women therefore, have more farming experience and information on crop management practices than men. The study by Tazeze *et al.* (2012) in the study conducted in Babilie district of Eastern Ethiopia argued that male-headed households were more likely to adopt improved crop variety and crop diversification at 5% and 1% significant level. This is so because, male-headed households are relatively flexible in search of improved crop varieties and in a better position to pull their labour force in order to adapt improved crop varieties and crop diversification. The other possible reason for this is that much of the farming activities are done by male while female are more involved in the processing, this gives male headed households an edge in terms of farming experience and information on various adaptation strategies and what is needed to be done in response to the climatic instability.

According to Deressa *et al.* (2009), education of the head of household increases the probability of adapting to climate change. The authors in their study in the Nile Basin established that education significantly increased soil conservation and changing planting dates as an adaptation method. A unit increase in number of years of schooling resulted in a 1% increase in the probability of soil conservation and a 0.6% increase in change in planting dates to adapt to climate change (Deressa et *al.*, 2009). Farmers with more education are more likely to have enhanced access to information than poorly educated farmers. Educated farmers are more likely to perceive climate change and adapt better (Madisson, 2006). Uddin *et al.* (2014) added that educated farmers have more knowledge and the ability to understand and respond to changes, forecast future scenario and have greater access to information and opportunities which encourages adaptation to climate. The study by Ndambiri *et al.* (2013) in the study conducted in Kenya found that farmers with higher levels of education are more likely to perceive climate change and adapt better, increases the probability of uptake of adaptation measures to climate change are more likely to have enhanced access to technological information than poorly educated farmers.

According to Hassan *et al.* (2008) argue that larger households have a larger pool of labour and as a result, they are more likely to adopt agricultural technologies than smaller households. According to Deressa *et al.* (2009), family sizes are associated with a higher labour endowment, which enable households to accomplish various agricultural tasks. For instance, households with a larger pool of labour adopt agricultural technology and use it more intensively because they have fewer labour shortages at peak times (Deressa *et al.*, 2009). A large family also divert part of its labour force into non-farm activities to generate more income and reduce consumption demands. The study by Abid *et al.* (2015) in the study conducted in Pakistan to establish farmers perception and adaptation strategies to climate change and their determinants found that an increase by one individual in the average household led to an increase in the likelihood of planting shade trees and increase in choice of soil conservation as adaptation measure.

According to Hassan *et al.* (2008), access to extension services is an important source of information on agronomic practices as well as on climate change. Farmers who have access to extension services are more aware of changing climatic conditions and to have knowledge of the various management practices that they can use to adapt to changes in climatic conditions. A study by Apata (2011) conducted in southwest Nigeria added that farmers access to information on climate change through extension agents and other sources such as televisions and radios creates awareness and favourable condition for adoption of farming practices that are suitable under climate change (Apata, 2011).

Access to climate change information is another essential factor, which may influence the adoption of farming technologies. Hassan *et al.* (2007) observed that the awareness by farmers of climate change attributes is of essence in as far as their adaptation decision-making process is concerned. Maddison (2006) and Nhemachena and Hassan (2007) observed that the awareness by farmers of climate change attributes - whether precipitation or temperature or both, is of essence in as far as their adaptation decision-making process is concerned. In this study, it was therefore expected farmers with access to climate change information were more likely to observe changes in climate and were therefore more likely to adapt than those without access to climate change information. The study by Abid *et al.* (2015) conducted in Pakistan emphasised that expected farmers with access to climate change information were more likely to observe changes in climate and were therefore more likely to adapt than those without access to climate change information.

Access to credit is an important determinant enhancing the adoption of various climate change strategies on agriculture. With more financial resources, farmers are able to make use of all their available information to change their management practices in response to changing climatic. For instance, with financial resources farmers are able to buy new crop varieties, new irrigation technologies and other important inputs they may need to change their practices to suit the forecasted climate changes (Nhemachema *et al.*, 2008). Abid *et al.* (2015) in the study conducted in Pakistan to establish farmers' perceptions of and adaptation strategies to climate change and their determinants found that access to farm credit is positively related to changing crop variety and increased irrigation and negatively related to the changing crop type, changing planting dates, planting shade trees, soil conservation, changing fertilizer and crop diversification.

Another factor that influences the adoption of climate change strategies is farmers' accessibility to the market places. The study by Abid *et a*l. (2015) conducted in Pakistan established that distance from the local market indicates that farmers located near to the local market have more chances to adapt to climate change compared to farmers who are far away from the market. Another study by Tazeze *et al.* (2012) found that market is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers. Better access to markets enables farmers to buy new soil and water conservation technologies and inputs they may need if they are to change their practices to cope with predicted changes in future climate. According to Ndambiri *et al.* (2013), long distances to market centres decrease the likelihood of farm adaptation and that market places provide important avenues for farmers to congregate and share information (Ndambiri *et al.*, 2013).

2.5 CHALLENGES TO CLIMATE CHANGE ADAPTATION FOR SMALLHOLDER FARMERS

Various factors hinder farmers to effectively adapt to temperature and rainfall variability. The study by Ndamani *et al.* (2016) conducted Ghana found that unpredictability of weather coupled with limited information makes it difficult for farmers to plan ahead. Lack of agricultural credit and subsidies limits farmer's ability to obtain resources required to deploy appropriate adaptation practice against climate change. Another study by Morton (2007) established that smallholder farmers are unable to store excess crop and sell them when prices are better because they do have better infrastructure and markets. The result of a study conducted by Centre for Environmental Economics and Policy in Africa across African countries showed that lack of access to credit or saving is one of the major problems encountered by farmers in adapting to the effects of climate change (Dewit, 2006). According to Deressa *et al.* (2009) barriers to adaptation to climate change in the Nile basin of Ethiopia indicates that lack of money is a major constraint to adaptation by farmers.

According to Ngigi (2009) information is a powerful tool for enhancing adaptation to climate change and variability. Due to abrupt increase in extreme weather events such as floods and droughts, farmers are left with no time to adapt because the smallholder farmers information on climate in order to adapt (Action aid, 2006). In Ghana, there is little climate projection due to lack of appropriate climate data. This is crucial since most of the farming depend on rain-fed agricultural system. Even when the climate information has been provided, it comes in a form of seasonal forecasts that may not be useful to a long-term climate planning. Information and awareness could serve as barrier to successful implementation of agricultural practice (Zwane *et al.*, 2016). Farmers' organizations and private sector in Sub-Saharan Africa including research is still very low compared to what is obtainable in developed countries such as Japan and Mexico (FAO, 1996). Sources of agricultural information through the internet are yet to expand to the rural areas of Nigeria, and may in fact not be able to because of language and cost barriers (Enete *et al.*, 2011). Insufficient weather and climate change forecast information increase the risk of failure when farmers adopt new technologies as adaptation measures. Poor and insufficient weather forecast information delivered to the district and commune level is recorded in the production plan reports of Tho Xuan district for period 2009-2013, had a negative impact in Tho Dien community in relation to failure crops of year 2009, 2010 and 2012. Lack of weather and climate forecast information for climate change adaptation was also noted by farmers in Red River and Mekong River Deltas which came late which was no longer required (Van *et al.*, 2015).

Lack of technology has the potential to seriously problem to the community since it limits the ability to implement adaptation. Many of the adaptive strategies for managing climate change involve technology such as protective structures, crop breeding and irrigation, flood management structures and drought proofing. The study by Ngigi (2009) in Sub-Saharan African established that technology choices are limited by inadequate financial resources and knowledge (Ngigi, 2009).

According to Gbetibouo (2009), inadequate financial resource constrains farmers to effectively adapt. Access to credit enable farmers with limited financial resource to purchase the inputs and equipment associated with adaptation. Lacks of financial resource have also prevented smallholder farmers in United State from accessing crop varieties that tolerate heat and drought conditions. Changing in crop varieties is extremely expensive and new planting take several years to reach its maximum productivity. Seeds for new tolerant varieties are expensive and require investments in new planting equipment. Controlling weeds costs several billions a year with majority spent on herbicides. Both herbicides use and costs are likely to increase as temperature and carbon dioxide increases (Karl, 2009). Lack of money to purchase farm inputs, such as hybrid seeds, fertilizers and farm implements, was perceived as an important barrier to farmers (Van *et al.*, 2015). Financial resources are obstacle for smallholders in their investments and decisions that they make in taking care of their land. Rural areas in have a much harder time accessing credit because banks encounter higher financial costs and constraints in these areas due to rural locations and related risks (Deininger *et al.*, 2007). The result of a study conducted by Centre for Environmental Economics and Policy in Africa across African countries showed that lack of access to credit or saving is one of the major problems encountered by farmers in adapting to the effects of climate change (Dewit, 2006). According to Deressa *et al.* (2009) the analysis of barriers to adaptation to climate change in the Nile basin of Ethiopia indicates that lack of money is a major constraint to adaptation by farmers. Farmers in Uganda are unable to take out loans because they do not qualify (Boucher *et al.*, 2008). Technology is costly, so most of smallholder farmers lack financial resources to adapt to changes in climate (Ngigi, 2009 and FAO, 2001). Smallholder farmers are illiterate with poor technological skills, which can be serious obstacles in accessing useful formal institutions that disseminate technological knowledge (DAFF, 2012).

Lack of reliable markets has also been found to be one of the main constraints faced by smallholder farmers to constitute to the successful implementation of climate adaptation strategies. Lack of markets is related of appropriate storage facilities. Lack of storage weakens the bargaining power of the smallholder farmers when it comes to negotiating the price of farm produce. So many of farmers cannot store their produce and therefore accept whatever price they are offered (Enete *et al.*, 2011). Many of South Africa farmers receive low prices for their products by selling them at their farm gate or local markets. However, these smallholder farmers could receive much higher prices by selling their goods by using marketing knowledge and selling skills as well as little recognition of opportunities for product diversification or the limits between market research and product development (DAFF, 2012).

According to FAO (2008), poor irrigation potential can most probably be associated with the inability of farmers to use the already existing water due to technological incapability. Most African farmers are resource poor and cannot afford to invest on irrigation technology to adapt to climate change in order to sustain their livelihood during harsh climate extremes such as drought which often causes famine. According to Ngigi (2009), lack of technology has a serious problem to smallholder farmers as it limits smallholder farmers their ability to implement adaptation strategies.

Insufficient knowledge concerning appropriate adaptations was identified as a barrier. The biggest barrier identified by smallholder farmers in Uganda is insufficient knowledge, because activities such as composting, mulching, rotating crops, or letting fields or strips lie fallow do not usually require any extra materials, they just require the expertise to implement them, which can be learned from a neighbour, extension officer and nearby farmer (Nkonya *et al.*, 2004 and Binns, 2012). Harvey *et al.* (2014) concluded that having access to agro meteorological or market information, could help inform farm management decisions, such as the choice of crops, planting dates and management strategies, and which could serve as early warning systems for floods and cyclones. According to Wilk *et al.* *(*2012*),* farming acknowledged the importance of knowledge passed down from elders, but also stressed that knowledge continually needs updating such as new techniques, equipment, breeding practices, crop varieties and pesticides.

According to Gbetibouo (2009) access to proper and extension services increases the likelihood to adaptation. Most of smallholder farmers lack proper information from the extension officers. The farmers asserted that lack of relevant information such as workshop and training has cost a major constraint. Roncoli *et al.* (2010) added that poor quality of government services such as lack of relevant knowledge and commitment by extension agents and unreliable predictions by the meteorological Department, farmers invested more than usual in farming expectation of abundant precipitation which did not materialize and their maize crop was drying in the fields. Another study by Benhin (2004) conducted in South Africa found that farmers with limited extension services asserted that the information provided is not helpful and not relevant to mitigate the effects of climate change (Benhin, 2004).

Lack of human capital has also been found to be a serious constraint for smallholder farmers. Farmers in sub-Saharan Africa, Ghana has reported difficulties in accessing such improved varieties of groundnuts are available; their prices are prohibiting making it difficult for many smallholder farmers to access. Financial barriers due to lack of facilities are one of the most important obstacles hindering the implementation of appropriate adaptation strategies (FAO, 2001). The majority of smallholder farmers are not capacitated with financial and are unable to meet the quality standards set by fresh produce markets (DAFF, 2012).

Institutional barriers are the challenges that restrict smallholder farmers from implementing better adaptation strategies to climate change and variability, institution play a crucial role in enhancing the capacity of local communities and proving mechanism that help to shape social and individual interaction within the society. Governmental institutions are the key to remove barriers to climate adaptation. In farming community, extension officer are supposed to be the link between the community and farmers by facilitating ways of farming to farmers (Ngigi, 2009). Poor institutional of agricultural institutions in Nigeria has served as one of the greatest constraints faced by women farmers. Institutional/organizational barriers limit farm women's access to farm support services such as extension, education, information services, cooperative and other relevant agricultural services. FAO (2001) survey showed that female farmers receive only 7% of all agricultural extension services world-wide and that only 11% of extension agents are women.

Lack of insurance constrains farmers to adapt to climate change. Insurance access for smallholders can bring further peace of mind for farmers, especially in light of weather shocks due to climate change. Traditional forms of insurance often occur between neighbours, but this system can leave the poorest groups out of luck (World Bank, 2007). Formal insurance is difficult to obtain because it requires upfront sums of money before the harvest that most farmers do not have, it requires a level of financial literacy that they often do not have, it is not beneficial every year, and it requires that a formal insurance system functions in their rural area (World Bank, 2007).

The study by Harvey *et al.* (2014) on extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar indicated that factor that increases farmer vulnerability is the remoteness of farm villages and lack of adequate road infrastructure. The roads are in a poor state and unevenly distributed, with many villages lacking roads that connect them to other villages and the main roads are often accessible only during the dry season. Zwane *et al.* (2016) also added that men and women in Garissa complained about the poor state of the roads, which become impassable during the rainy seasons. Roncoli *et al.* (2010) on adaptation to climate change for smallholder agriculture in Kenya also argued that poor road infrastructure has hindered movements and the flow of farm produces to markets, and in-put requirements such as seed and fertilizers to farmers. According to Enete *et al.* (2011), shortage of storage facilities poses serious threats to farmers in food preservation, most especially during harvest periods. As a result, most crop farmers are often in a rush to send farm produce to market immediately after harvest, not minding the associated low prices (Enete *et al.*, 2011). Many of these farmers receive low prices for their products by selling them at their farm gate or local markets. However, these smallholder farmers could receive much higher prices by selling their goods by using marketing knowledge and selling skills as well as little recognition of opportunities for product diversification or the limits between market research and product development (DAFF, 2012).

Smallholder productivity is also affected by lack of education to which it could help build skills needed to manage on and off farm production system more efficiently and raise smallholder adoption of innovative and high return technologies (Fan *et al*, 2013). The report of IFAD (2007) conducted in Nigeria confirmed that the poor state of the country's education has also had its toll on the poor people, majority of who are farmers in rural areas. In addition, they are faced with limited social services and infrastructure. FAO (2008) reported that about 90% of Nigeria's food is produced by small-scale farmers who cultivate small plots of land and depend on rainfall rather than irrigation systems as a result of their low knowledge base, access to facilities and poor financing (FAO, 2008).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

Qualitative and Quantitative approaches were used in this study. Qualitative research is dialectic and interpretive. It involves open discussion, questions and answer session and depth understanding with an individual. Quantitative research is objective and seeks explanatory laws and involves numbers. In this study purposive sampling technique was used and questionnaires were administered.

3.2 PRIMARY DATA COLLECTION

A multi-stage sampling approach was used in the primary data collection. Firstly, simple random sampling was used to select 2 local municipalities (Lepelle Nkumpi Local Municipality and Polokwane Local Municipality) out of 5 municipalities in Capricorn District Municipality. From each of the selected 2 selected municipalities, villages were clustered into traditional administrative areas. Out of the 19, 7 traditional administrative areas were randomly selected in Polokwane Municipality and 5 out of 10 traditional administrative areas in Lepelle-Nkumpi Municipality (Table 3.1). In the selected traditional administrative areas, a total of 23 villages in Lepelle-Nkumpi Local Municipality and 31 villages in Polokwane Local Municipality were randomly selected to be studied (Table 3.1).

In the selected villages, purposive sampling was used to select farmers whom questionnaires were administered to. For the farmer to be administered a questionnaire, he/she had to be a maize farmer producing to sell, with a land size of between 0.5 and 5 ha, and must not be established as a commercial farmer.253 questionnaires were administered which solicited information on the socio-economic characteristics of the farmers, the adaptation options the farmers are using, the factors influencing the choice of adaptation option and challenges these farmers faced.

Table 3.1: Sampled villages from the traditional authorities selected from the Polokwane and Lepelle-Nkumpi Local Municipalities

Local Municipality	Traditional Authority	Number of villages	Villages	Number of farmers
Lepelle-Nkumpi Local Municipality	Mathabatha	4	Lekgwareng	2
			Makgoba	12
			Madikelele	5
			Mphaaneng	7
	Mphahlele	7	Mamaolo	5
			Makurung	2
			Tooseng	1
			Sefalaolo	10
			Dithabaneng	15
			Mashite	10
			Mooiplas	6
	Mafefe	4	Ramonwane	5
			Mahlatjane	10
			Ngwaname	5
			Ga-Mampa	8
	Ledwaba	3	Matome	1
			Hwelereng	1

			Makotse	2
	Kekana	5	Mogoto	3
			Madisha-Ditoro	6
			Molapo	5
			Bolahlakgomo	3
			Byldrift	12
Polokwane	Mothiba	4	Chebeng	2
			Ga-Kama	8
			Ga-Mobotsa	1
			Ga-Mogano	1
	Moloto	5	Mamatsha	2
			Makotopong	1
			Mankgaile	4
			Ramogaphota	2
			Sebayeng	1
	Maja	4	Ga-Molepo	6
			Kopermyn	9
			Laaste Hoop 7	7
			Thokgwaneng	10
	Molepo	5	Badimong	2
			Boyne	7
			Ga-Mahlantlhe	4
			Matshela-Pata	2
			Mountain Views	3
	Mojapelo	5	Bergvley	2
			Cottage	2
			Dichueneng	5

			Klipspruit	2
			Mogokubung	1
	Mamabolo	4	Ga-Makanye	7
			Ga-Thoka	2
			Nobody	5
			Ntshichane	2
	Dikgale	4	Dibibe	2
			Ga-Makgoba	7
			Makgoba	5
			Mantheding	3

(Source: researcher, 2016)

3.3 SECONDARY DATA COLLECTION

The secondary data sources included literature from both published and unpublished research papers and reports on the issues of the adaptation strategies to temperature and rainfall variability that are employed by smallholder maize farmers. The meteorological data on rainfall and temperature (monthly and annually) collected over a period of 20 years (1993-2013) were obtained from South African Weather Service (SAWS).

3.4 DATA ANALYSIS AND PRESENTATION

In order to understand the effects of temperature and rainfall variability and constraints faced by smallholder maize farmers in Capricorn District Municipality, descriptive statistics tool such as percentage and frequency were used.

In order to establish changes in temperature and rainfall over the 20-year period, simple linear regression were used based on the following equation.

$$Y=mx+c$$

Where Y is either temperature or rainfall of specific year, x is the specific year, c is the intercept of the straight line represented by equation and m is a constant determined by the following equation.

$$m = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sum(xi - \bar{x})2}$$

Where xi is the independent variable representing the year (1993-2013) and yi is depended variable (rainfall in mm) representing temperature (°C) or rainfall (mm) for the year. Whereas $\bar{x}$ and $\bar{y}$ is average for temperature and rainfall. Significance of trend has been judged by using R^2 value. The R^2 (coefficient of determination) is a key output of regression analysis. R^2 is interpreted as the proportion of the variance in the dependent variable that is predictable from the independent variable.

- The coefficient of determination is the square of the correlation (r) between predicted y scores and actual y scores; and ranges from 0 to 1.
- The coefficient of determination is also equal to the square of the correlation between x and y scores.
- An R^2 of 0 means that the dependent variable cannot be predicted from the independent variable.
- An R^2 of 1 means the dependent variable can be predicted without error from the independent variable.
- An R^2 between 0 and 1 indicates the extent to which the dependent variable is predictable. For example, if R^2 of 0.10 means that 10% of the variance in *Y* is predictable from *X*; an R^2 of 0.20 means that 20% is predictable; and so on.

R^2 is calculated from the following equation.

$$R^2 = \frac{\{\sum(xi - \bar{x})(yi - \bar{y})\}2}{\{\sum(xi - \bar{x})2\}2\sum(yi - \bar{y})2}$$

In order to understand the factors that determining smallholder maize farmers adaptation strategies to temperature and rainfall variability, **the multinomial logistic regression (MNL)** model was used. The MNL model for choice of adaptation strategies specifies the relationship between the probability of choosing adaptation option and set of explanatory variables. The MNL allows the analysis of decisions across more than two classes, allowing the determinant of choice for different categories (Obayelu *et al.*, 2014).

The estimation of the Multinomial logistic regression model for this study was undertaken by normalising one category which is referred to as the base category. In this analysis, the base category was the change in crop varieties.

The decision of whether or not to use any adaptation option fell under the general framework of utility and profit maximization. Supposing that farmer who seeks to maximize the present value of expected benefits of production over a specified time horizon, and must choose among a set of *J* adaptation options. The farmer *i* decide to use *j* adaptation option if the perceived benefit from option *j* is greater than the utility from other options (say, *k*) depicted as

$$U_{ij}\ (\beta_j X_i+\varepsilon_j)>U_{ik}\ (\beta_k X_i+\varepsilon_k),\ k\neq j$$

Based on the above relationship the probability that a household will use option *j* from among a set of climate change adaptation options was defined as follows:

$$\begin{aligned} P(Y=1/X) &= P\ (U_{ij}>U_{ik}/X) \\ &= P\ (\beta'_j Xi+\varepsilon_j-\beta'_k X_i-\varepsilon_k>0/X) \\ &= P\ ((\beta'_j-\beta'_k)\ Xi+\varepsilon_j-\varepsilon_k>0/X) \\ &= P\ (\beta^* X_i+\varepsilon^*>0/X) \\ &= F\ (\beta^* X_i) \end{aligned}$$

Where

P is a probability function;

ε^* is a random disturbance term,

β^* is a vector of unknown parameters that can be interpreted as the net influence of the vector of explanatory variables influencing adaptation,

F (β^*Xi) is the cumulative distribution of ε^* evaluated at β^*Xi.

The exact distribution of *F* depends on the distribution of the random disturbance term, ε^*.

More especially, the assumption requires that the probability P, of using certain adaptation method by given farmers needs to be independent from the probability of choosing another adaptation method that P_{ij}/P_{ik} is the independent of the remaining probabilities. To describe the MNL model, let *Y* be a random variable representing the adaptation measure chosen by any farm household. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option *Y* and the set of explanatory variables X_i as follows:

$$P\ (y=y/x) = exp\ (x\beta_j)/\ [1+\sum_{K=1}^{J} (exp\ X\beta j) = \varepsilon,\ j=1.....j$$

Where β_j is a vector of coefficients on each of the independent variables X.

In MNL Model 14 adaptation strategies were grouped into 8 closely related choices of the same category. The replacement of change in harvest time and change in planting dates with “change in planting season” since it involves both planting season from planting to harvesting. Pesticides, use of traditional method, burning of locusts, blue death and use of ashes were groups in the same category labelled “pesticides” since they are considered the purpose for controlling pest in soils. Mulching (use of compost) and making of furrows were grouped together in the same category labelled “conservation agriculture technique” since they conserve water.

Y_1= manure

Y_2= change in planting season

Y_3= crop rotation

Y_4= pesticides

Y_5= weeding

Y_6=irrigation

Y_7= conservation agriculture techniques

Y_8= do nothing

Unbiased and consistent parameter estimates of the MNL model in the equation requires the assumption of independence of irrelevant alternatives to hold. More specifically, the assumption requires that the probability of using a certain adaptation method by a given household needs to be independent from the probability of choosing another adaptation method by the same household.

Table 3.2: Independent (explanatory) variable used in the multinomial logistic regression model

Variables	Description	Value	Expected sign
Household characteristics			
Age	age of the farm household	Years	-/+
Gender	gender of the head of the farm household	1=male, 0=female	-/+
Education level	Number of years of formal education attained by the head of the household	Years	+
Household size	number of family member of a household	Number	-/+
Farming experience	Number of years of farming experience for the household	Years	+
Institutional factor			
Farm income	income from farming activities	Number	-/+
Non-farm income	income from off-farm activities during the survey year	Number	-/+
Extension services	if the household has access to extension services	1=yes., 0=no	+
Access to finance	if the household has access to finance from any source	1=yes, 0=no	+

(Source: researcher, 2016)

3.5 CONCLUSION

This chapter provided information about the area where the study took place. It also covered the sample selection techniques in the study area. Data collection and analysis were done. A descriptive statistics was conducted, followed by regression models analysis (Multinomial Logistic Regression Model) was used to determine the existence of a relationship between variables and adaptation strategies.

CHAPTER 4

THE IMPACTS OF TEMPERATURE AND RAINFALL ON SMALLHOLDER MAIZE FARMERS

4.1 INTRODUCTION

The Second Assessment Report published in 1996 identified evidence suggesting a discernible human influence on global climate (IPCC, 1996). This was also established in the Third Assessment Report published of 2001, where it was argued that majority of the warming during the preceding 50 years 66% to 90% of it attributed to greenhouse gas emissions caused by human activities. Over the twenty first century, this warming trend, and changes in precipitation patterns have continued and have been accompanied by a rise in sea level and an increased frequency of droughts and floods (IPCC, 2001). According to the IPCC's Fourth Assessment Report (IPCC 2007), observations show that the earth's surface temperature has risen, on average, by 0.74 °C in 1906–2005. Satellite observations show that the average volume of Arctic ice cap has decreased by 2.7% per decade after 1978. In summer, the shrinking of the ice surface area has been even more rapid, at 7.4% per decade. Furthermore, oceans have warmed, leading to the melting of snow and ice has accelerated and the sea level has risen.

It was observed that the temperatures in Capricorn District Municipality have increased by 0.0131°C per year between 1993 and 2013. Changes in rainfall were not steady as were the temperature. Annual rainfall patterns for the period 1993 to 2013 was irregular and quite variable from year to year. In 1993 the annual increase of rainfall was 5 mm, and then increased in 1994 by 7.9mm and dropped again to 6.7 mm in 1995. The distribution of rainfall varied until 1999 where the amount of rainfall was 4.9 mm. From the year 1999 (4.9 mm) to 2000(11.7 mm) the amount of rainfall increased by 6.8 mm and continued to decrease and fluctuate until 2009 (7mm). The rainfall pattern from 2009 continued to fluctuate with slight changes.

The study established that there is a change in temperature and rainfall as well as increasing frequency and severity of extreme events such as drought and flood condition. This has led to smallholder maize farmers in the Capricorn District

Municipality facing numerous risks to their maize production including increase in pests and disease outbreak, loss of soil moisture, crop failure, change in growing season, low crop yield, drying out of maize, increase in fungal diseases and an increase in the occurrence weeds and invader plants.

4.2 CHANGES IN TEMPERATURE AND RAINFALL BETWEEN 1993 AND 2013

4.2 .1 CHANGES IN TEMPERATURE

Figure 4.1 represent the monthly maximum temperature for over a period of 20 years. From the graph, maximum temperature of Capricorn District Municipality ranged between 18.9 °C and 30.8°C for the 20 years under study. The results show that Capricorn District Municipality used to experience shorter maximum temperature during winter season (May, June and July) but they were elongated (May, June, July and August). From the analysis, it can be noticed that temperatures have increased and were higher than normal in January 1993 (30.2°C) November 1994 (28.4°C), February 1995 (30°C), October 1996 (27.9°C), December 1997 (29.6°C), February 1998 (29.9°C), February 1999 (27.6°C), December 2000 (27.8°C), January 2001 (29.5°C), January 2002 (29.3°C), February 2003 (30.7°C), November 2004 (30.3°C), February 2005 (29.6°C), December 2006 (29.1°C), February 2007 (30.8°C),February 2008 (29.3°C),December 2009 (28.5°C), February 2010 (28.5°C), March 2011 (29.7°C) and February 2012 (30.8°C). This is in line with LEDET (2015) findings where it was established that average annual maximum temperatures for the last 20 years in Lephalale, Phalaborwa, Mokopane and Tzaneen displayed an increasing trend. In South Africa as a whole there have been an average increase of 0.5°C for the last 10 years (1998-2008) than in 1970 (Gbetibouo, 2009). Kruger *et al.* (2004) examined the period 1960–2003 and found that in South Africa reported increases in annual mean temperatures, with strongest warming having occurred in the interior of the country and during autumn months.

Fitting on the linear trend line, it is observed that the temperatures in the study area increased by 0.0131°C per year. As indicated coefficient of determination in Figure 4.2 (0.0084) changes in annual temperature in Capricorn District Municipality was not statistically significant.

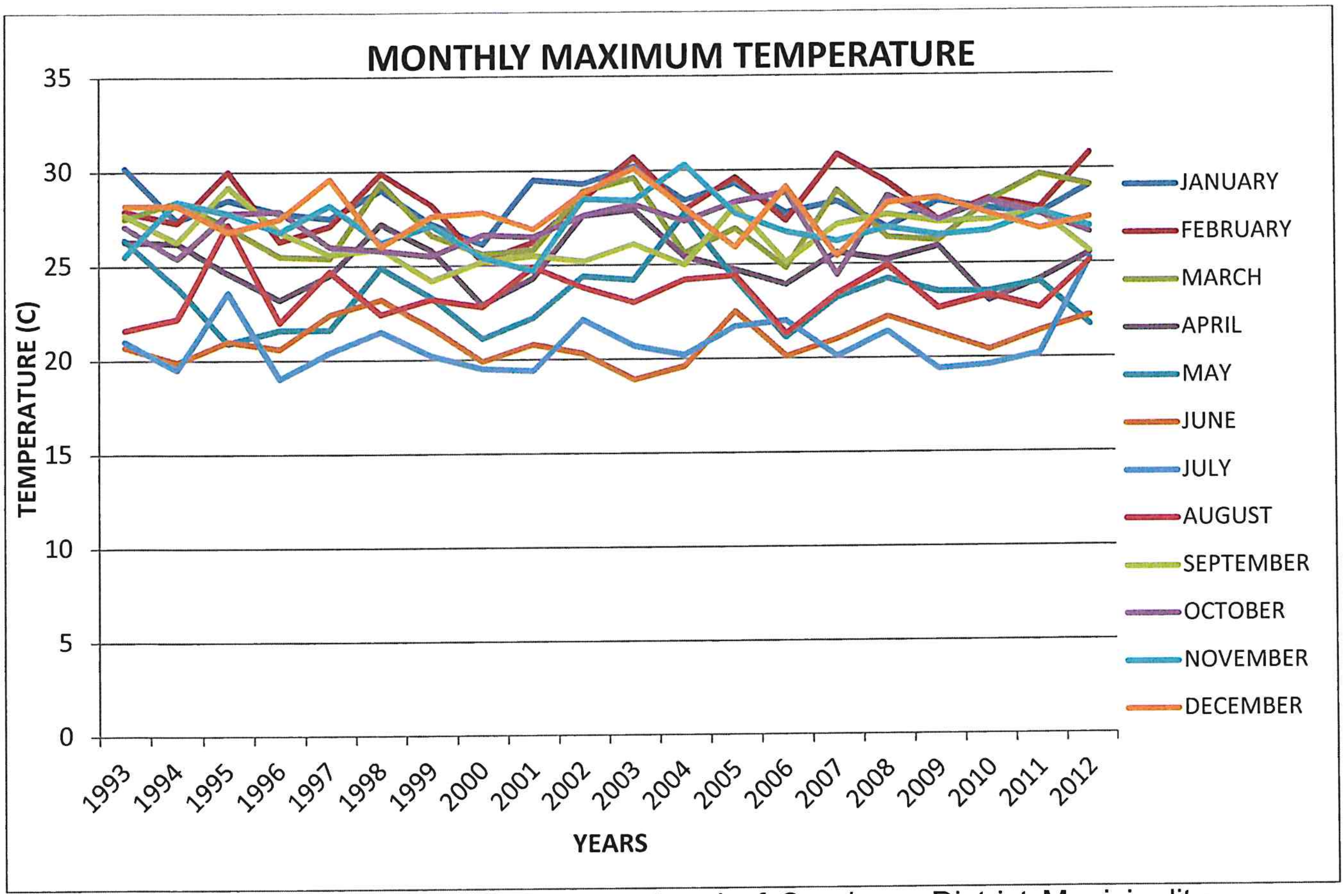

Figure 4.1: Monthly maximum temperature trend of Capricorn District Municipality 1993-2011(Source: SAWS, 2015)

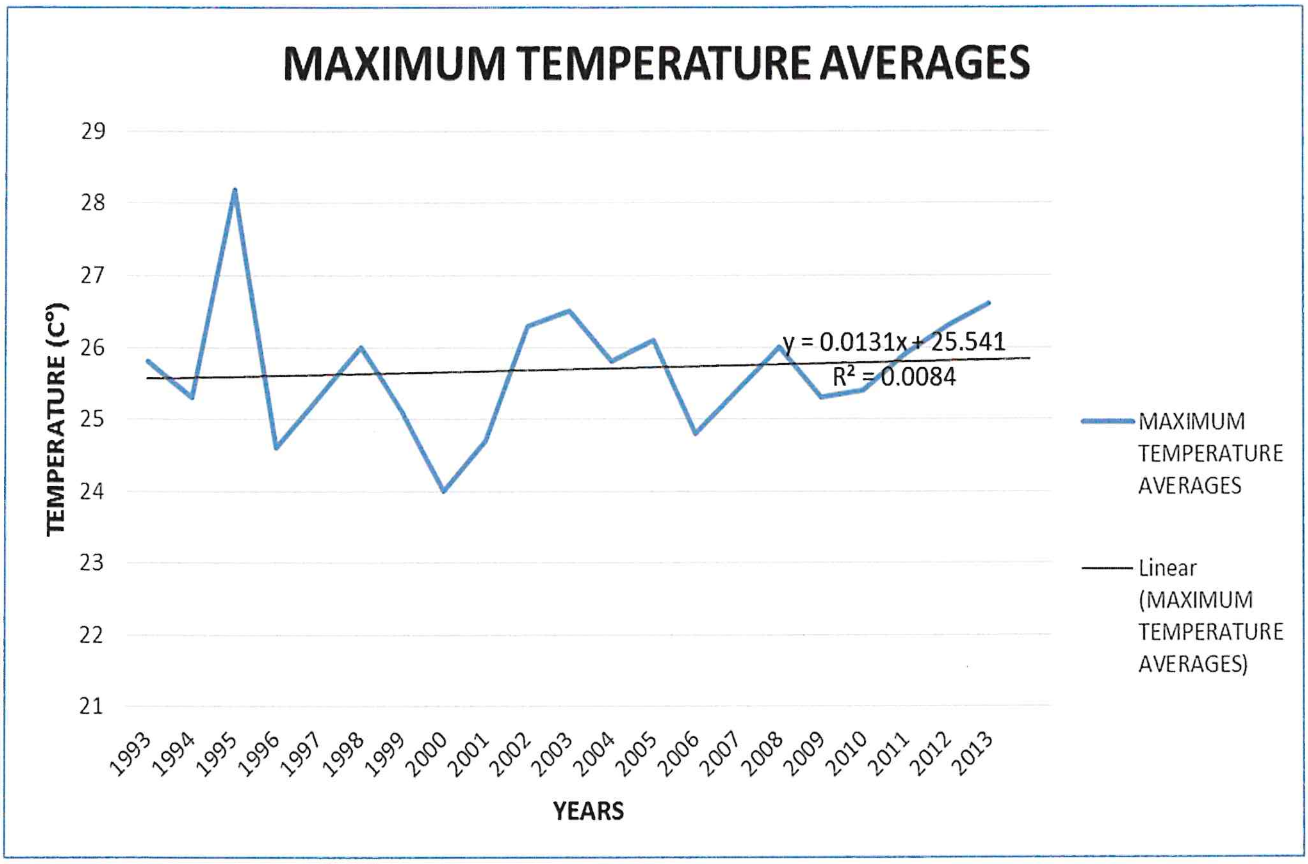

Figure 4.2: Annual maximum temperature trend of Capricorn District Municipality 1993-2011 (Source: SAWS, 2015)

Figure 4.3 indicate that the minimum monthly temperature fluctuated and varied throughout the 20 years under study. The highest minimum month temperature was in January. Within 20 years (1993-2013), Capricorn District Municipality experienced the highest minimum monthly temperature of less than 20 °C except for in October 2001 by 23.7°C and April 2008 by 20.9°C. From the analysis, it can be noticed that that the minimum temperature are fluctuating and decreasing from year to year.

From Figure 4.4, it can be seen that the annual minimum temperature decreased at a rate of 0.0238 per year. R^2 values (0.0437), however, indicate a low statistical significance of these changes. The study by LEDET (2015) established that Limpopo Province experienced an increase in minimum temperature of 0.5° C to 1.2°C between 1986 and 2014 which is in line with this study's findings. Mackellar *et al.* (2014) also established that although there were changes in minimum temperature in Limpopo Province, the rate of change was a 0.011 °C/year which is lower than what this study established.

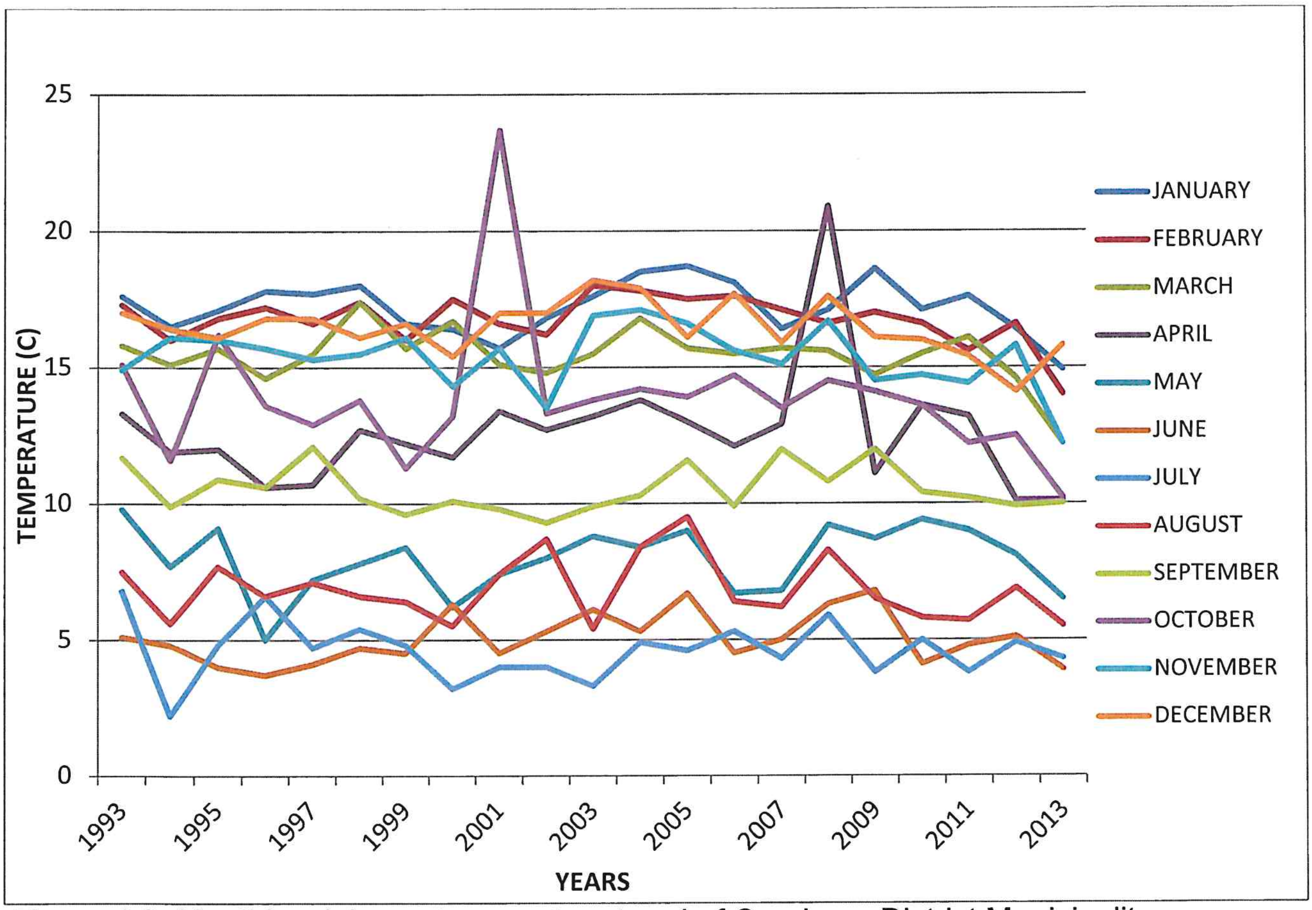

Figure 4.3: Monthly minimum temperature trend of Capricorn District Municipality

(Source: SAWS, 2015)

Figure 4.4: Annual minimum temperature trend of Capricorn Municipality (Source: SAWS, 2015)

4.2.2 CHANGES IN RAINFALL

Figure 4.5 present the average monthly rainfall (in mm) from 1993 - 2013. It can be noticed from Figure 4.5 that the Capricorn District Municipality was a rain scarce area. By looking at the graphs, the trend varied drastically and there was no obvious pattern. For example, in 1994 the highest rainfall experienced was in April at 37.8 mm, then dropped to 27.6 mm in February 1996 and decreased to 22, 7 mm in January 2003, drooped again to 19.6 mm in November 2005, August 2011 to 19, 2 mm and continued decreasing. It can therefore be concluded that the region is becoming drier and drier with time.

Generally, Limpopo province receives rainfall in November, December, and January but this study found that this is not the case. For example, in August 2002 (19.2mm), October 1999 (10.1mm), February 1996 (27.6mm), March 1998 (12.5mm) and April 1994 (37.8mm). This implies that the rainfall month in the study period shifted from August to April lasting longer than usual and it's decreasing from years to years and it is likely to experience shortage in rainfall in the coming years. The typical rainfall in

Limpopo Province occurs mostly during summer months preferably in October to March (DEA, 2013; LEDET, 2015, Benhin, 2004 and Tshiala *et al.,* 2011). This contradicts with the findings from the study area indicating that the rainfall is really changing from years to year to year.

Looking at the trend line, the rainfall ranged between 0 mm and 19.2 mm. The trend analysis (Figure 4.6) indicates that the annual rainfall pattern for the period 1993 to 2013 was irregular and quite variable from year to year. From the graph, in 1993 the amount of rainfall was 5 mm, and then increased in 1994 by 7.9mm and dropped again to 6.7 mm in 1995. The distribution of rainfall varied until 1999 where the amount of rainfall was 4.9 mm. From the year 1999 (4.9 mm) to 2000(11.7 mm) the amount of rainfall increased by 6.8 mm and continued to decrease and fluctuate until 2009 (7mm). The rainfall pattern from 2009 continued to fluctuate with slight changes. In figure 4.6, a decreasing trend is observed and the trend is 0.015mm per year period. But the R^2 value is 0.0032 which indicates a poor statistical significance of the trend.

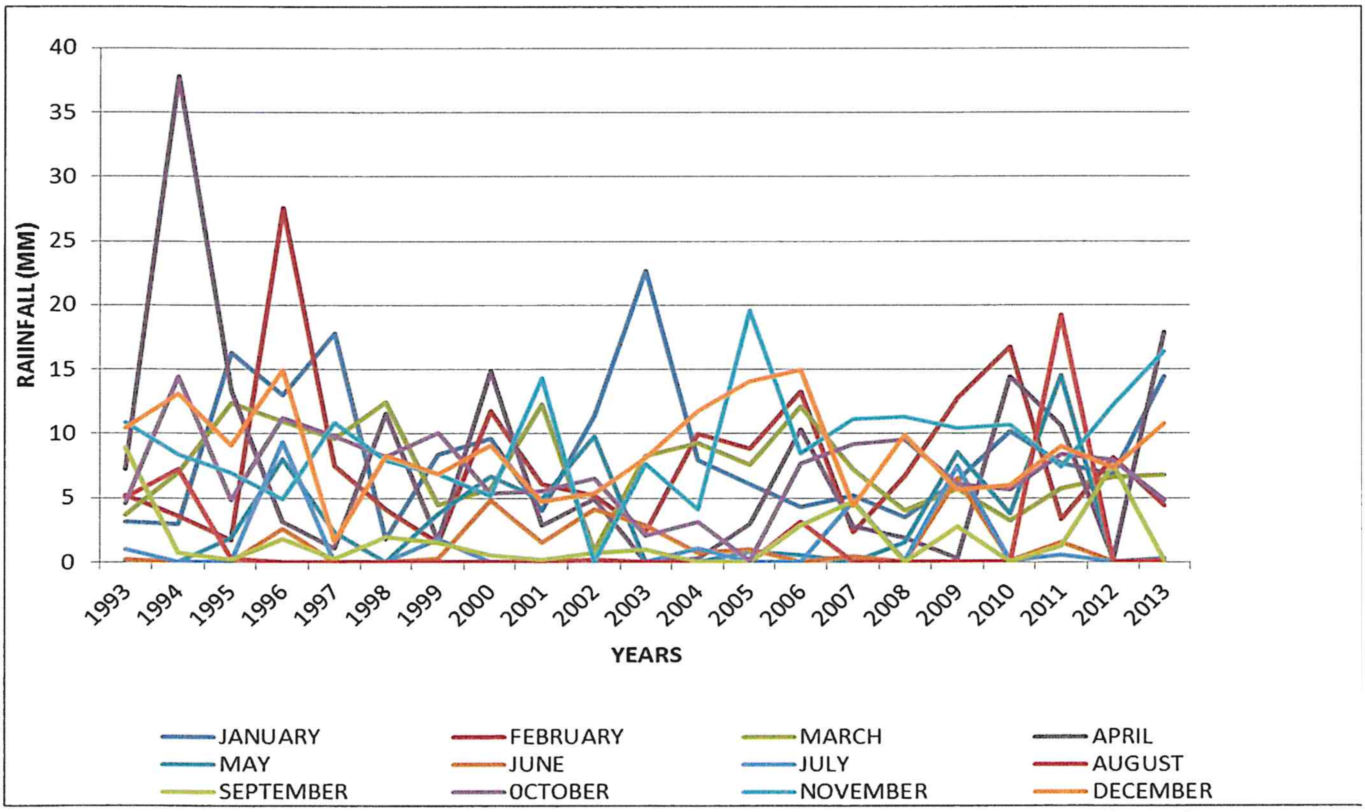

Figure 4.5: Monthly rainfall trend of Capricorn District Municipality (Source: SAWS, 2015)

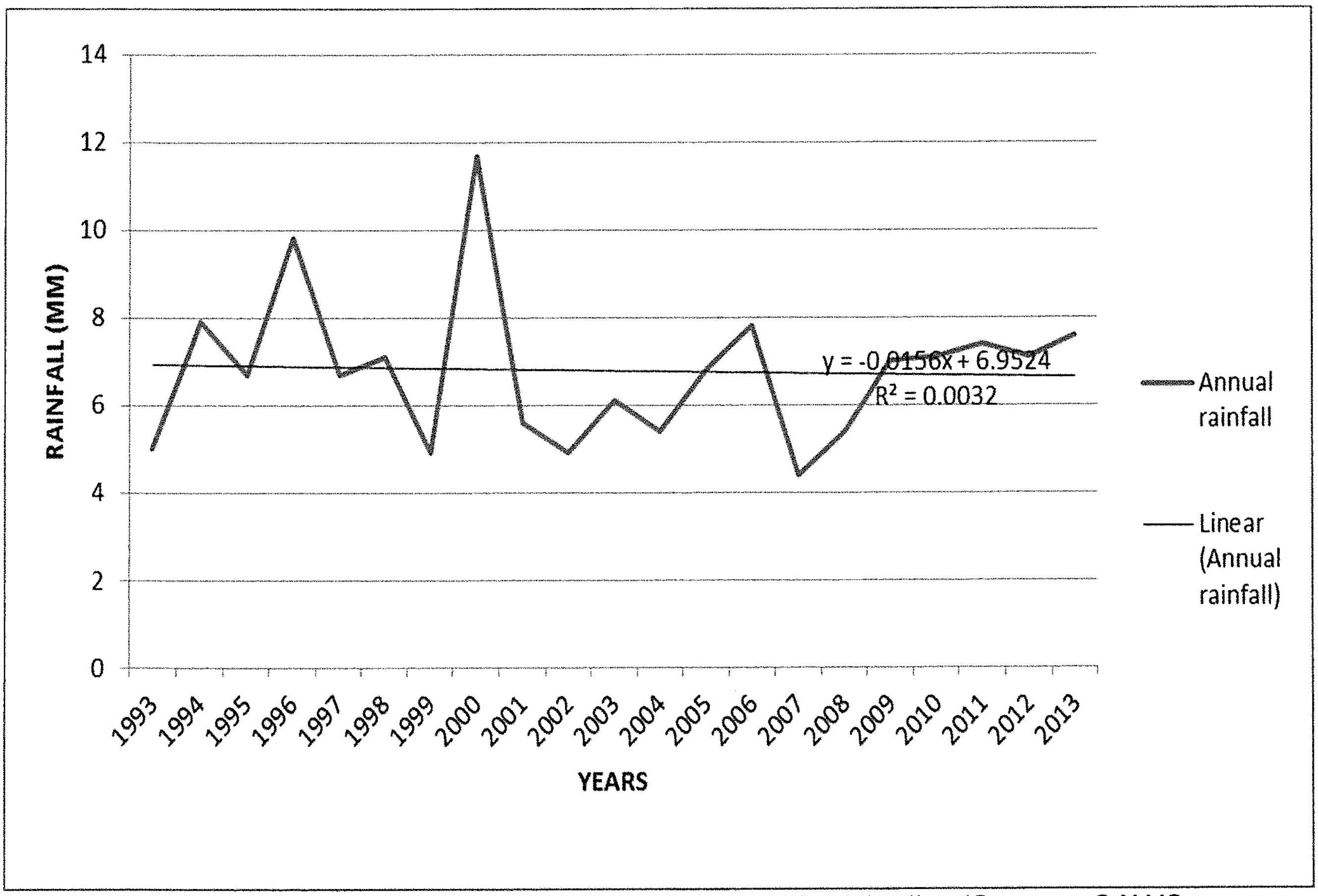

Figure 4.6: Annual rainfall trend of Capricorn District Municipality (Source: SAWS, 2015)

4.3 TRENDS AND FREQUENCY OF CLIMATIC ANOMALIES IN CAPRICORN DISTRICT MUNICIPALITY BETWEEN 1993 AND 2013

Figure 4.7 to 4.10, represents the rainy days. The highest rainy days has been observed in November 2001 and 2006 with 16 rainy days. But in November 2002, the study period experienced no rainfall the whole month indicating that there were drought incidents. Looking at the trend lines, the number of rainy days in November decreased by the rate of 0.16 per year December increased by 0.06 per year and January increased by 0.01 per year. It can be concluded that number of rainy days are decreasing. Therefore, the decrease in the amount of rainfall is likely to lead to the occurrence of drought condition.

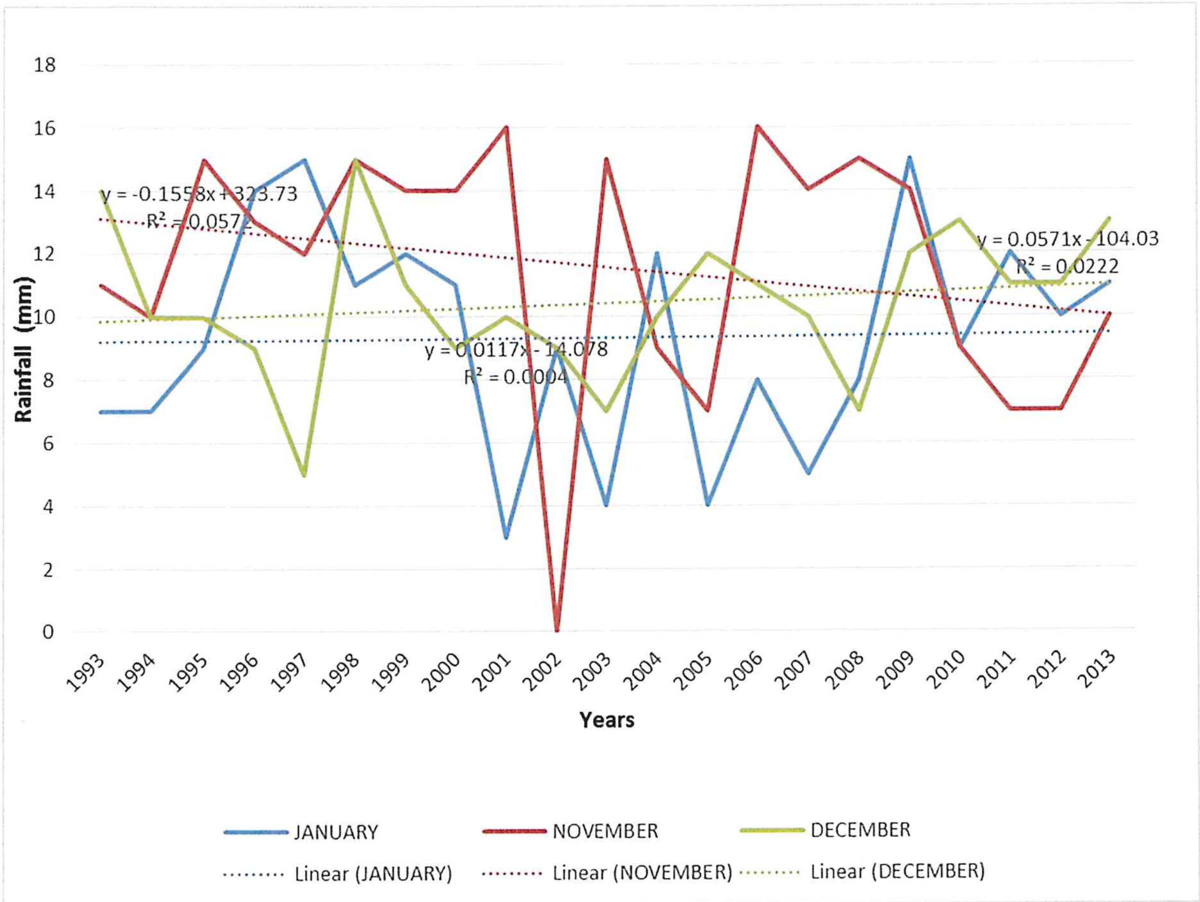

Figure 4.7: summer rainy days (Source: SAWS, 2015)

The summer rainfall in Capricorn District Municipality extended to autumn season (Figure 4.8) with the highest peak of 21 rainy days in April 2007 followed by 20 rainy days in March 2012. The same season autumn, February also experienced rainfall with 16 rainy days in 2006. This is not the case in Capricorn District Municipality since within the 20 years period it experienced the highest in April than February. Besides that, rainfall in Limpopo Province has shown high variability and less number of rainy days especially during autumn months (LEDET, 2015). Thomas *et al.* (2007) indicated that shifts were also observed in Limpopo for the 1950 and 2000 period, where there has been a tendency for a later seasonal rainfall onset accompanied by increased dry spells and fewer rain days. Therefore, it can be concluded that throughout the study period, the number of rainy days in February, March and April is irregular with no obvious pattern. As indicated in Figure 4.9, the study period experienced rainfall with the highest peak 11 rainy days in June 2000. Within 20 years (1993-2013), the rainy days in May ranges from 8 and 0 rainy days and 3 and 0 rainy days in July. Generally, the numbers of rainy days are irregular and decreasing from years to years. Mackellar *et al.* (2014) also concluded for a

50year period (1960-2010) large reductions occur in the number of rain days in December, January and February and Mach, April and May.

Figure 4.10, indicates that the study area experienced the highest rainfall of 31 days in August which was unusual. Besides that, it has also experienced the lowest rainy days of 11 days between 1993 and 2014. Also looking at the trend line for August (0, 0091 days per year) and September (0, 07 days per year) indicated that there has been a decrease in rainy days and the increase in October (0,153 per year). This finding was supported by the study by Tshiala *et al.* (2011) that from 1960 to 2003, 85% of the rainfall in Limpopo Province occurs during summer month (October to March).

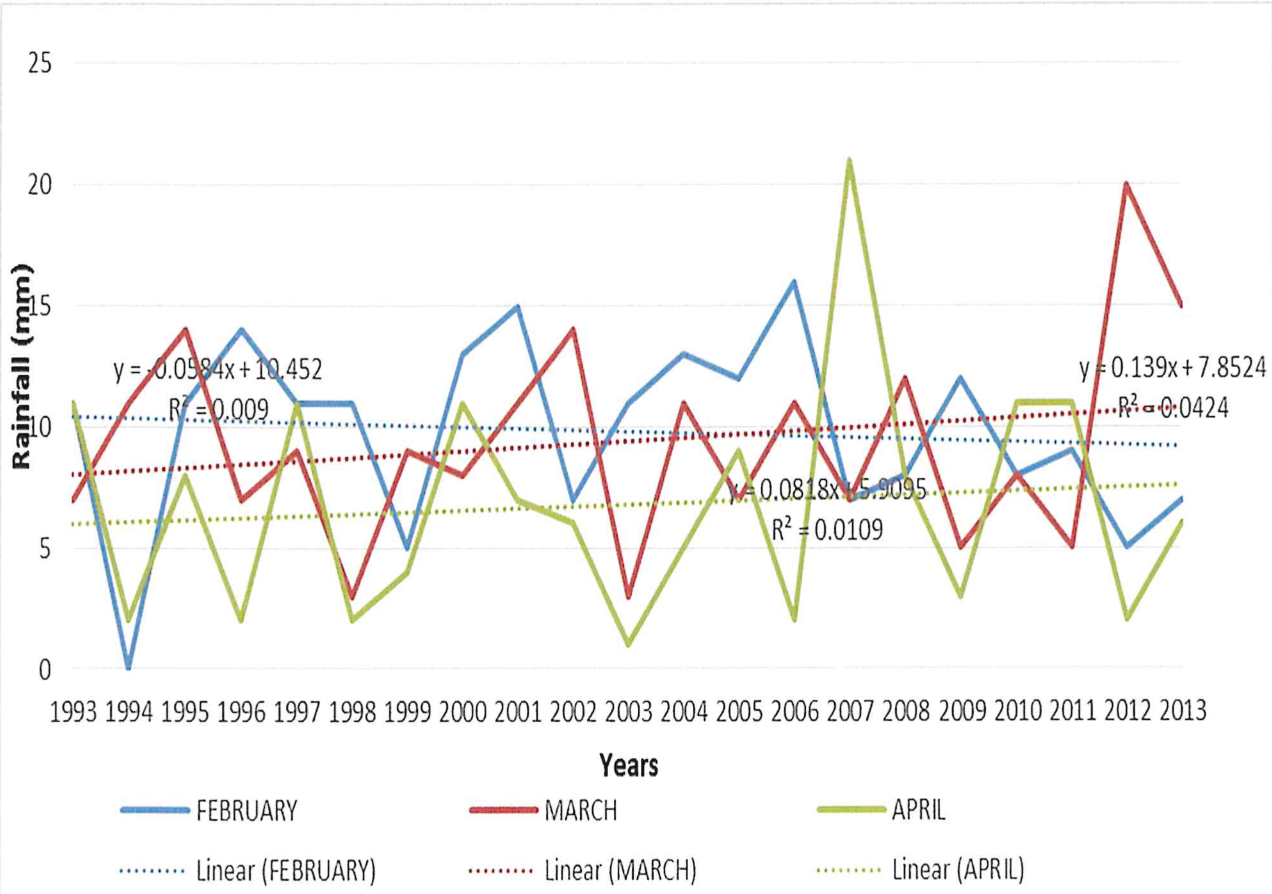

Figure 4.8: Autumn rainy days (Source: SAWS, 2015)

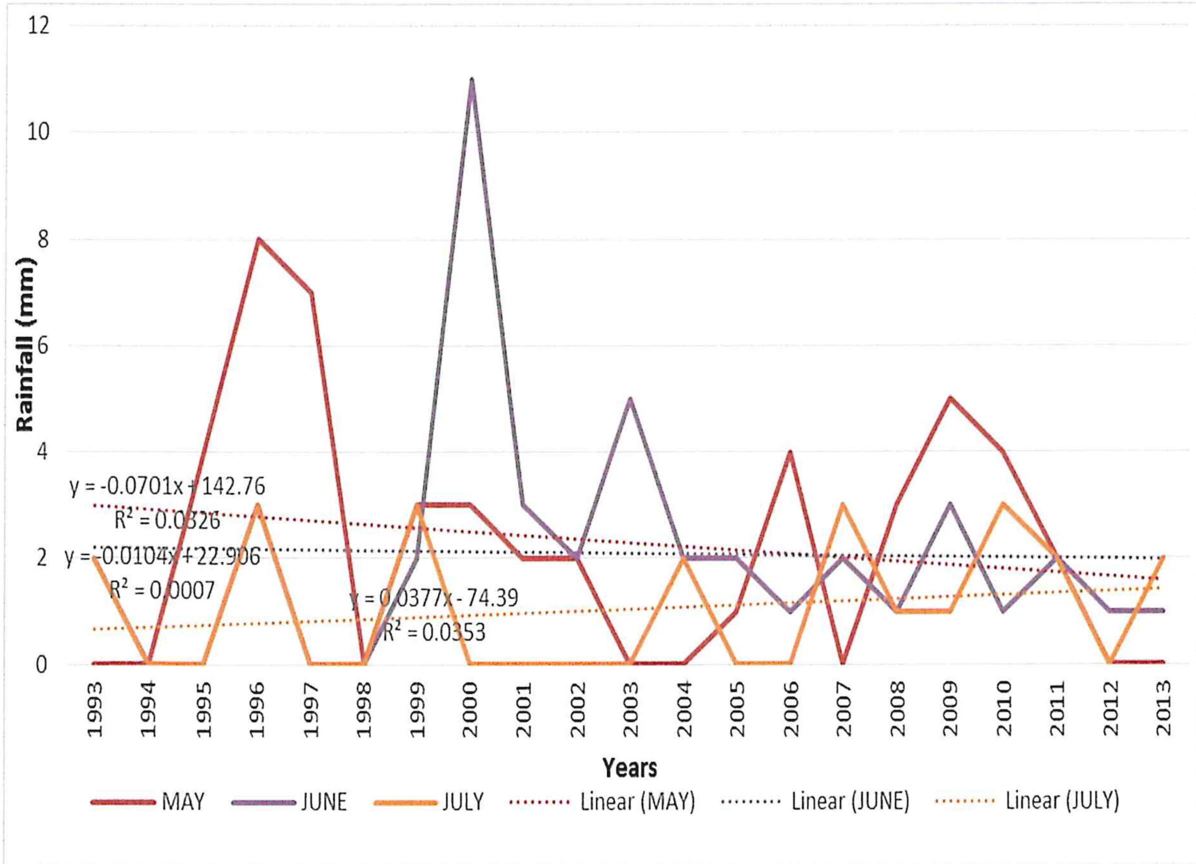

Figure 4.9: Winter rainy days (Source: SAWS, 2015)

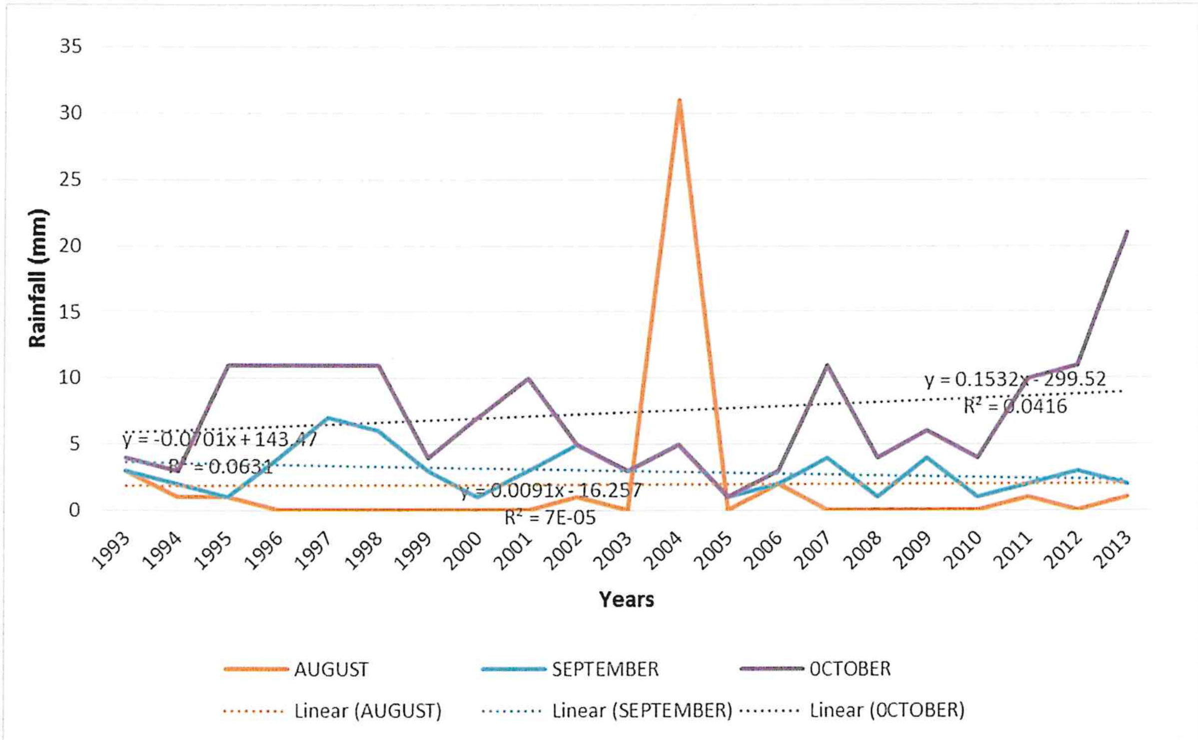

Figure 4.10: Spring rainy days (Source: SAWS, 2015)

Figure 4.11, it can be noticed that for the 20-year period (1993 to 2013) Capricorn District Municipality experienced highest of frequency of rain free days of 23 days in1993, 22.6 rain free day's in1999, 22.8 free days in 2008 and 22.8 rain free days in 2011. The greatest decrease occurred in 1998 by 21.5 rain free days to 14.8 rain free days in days. The annual trend indicated that the number of rain free days increased at the rate of 0.0957 in a year. Also looking at the annual trend line, the coefficient of determination (R^2) value (0.0639) indicates a weak statistical significance of these changes. But generally, the trend line indicates that the frequency of drought conditions in Capricorn District Municipality is increasing. Kruger (2006) demonstrated that increased dry spell duration is also evident for much of the Free State and Eastern Cape, and decreases in wet spell duration have been observed for parts of the Eastern Cape and the north-eastern parts of South Africa during 1910–2004. This is in concurrence with drought conditions in Capricorn District Municipality as established in this study.

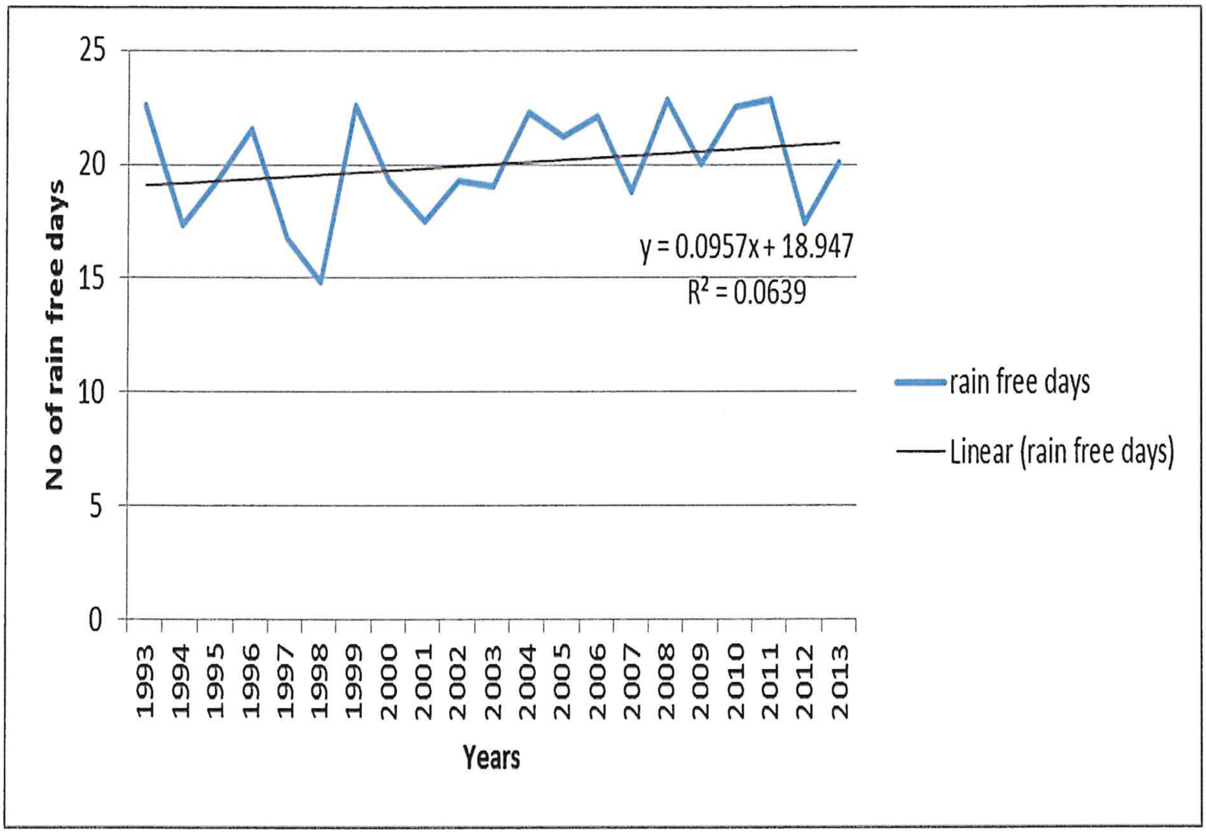

Figure 4.11: Annual frequency of drought condition (Source: SAWS, 2015)

4.4 FARMERS' NARRATIVES ON CHANGES IN TEMPERATURE IN CAPRICORN DISTRICT MUNICIPALITY

From Figure 4.12, 95% of the farmers in interviewed in the study area indicated that they experienced long term changes in temperature. 66% of them indicated that there was a general increase in temperature and that the temperatures are getting warmer day by day. Only 13% of the smallholder maize farmers indicated that the temperatures decreased while 5% noticed no change in temperature. It was only 16% who observed that there has been an alteration in climatic conditions. One of the farmers said that:

"When we were young, we used to find some mist on the grass and ice on the well in the morning during winter when we used to collect water but these days there is no such thing since the seasons are changing and becoming warmer"

16% of the farmers indicated that they noticed that the summer and winter season are changing. The winter seasons were either too cold or getting warmer than usual from year to year. The winter season has become longer than usual, starting earlier in April.

On other climatic variables, farmers noticed the change in climatic range where the temperatures are becoming hotter than usual and repeated heat waves, especially in November and December. It is becoming windy, dusty and sometimes drier but this could be due to vegetation decimation. There also indicated an increase in the occurrence and frequency of drought conditions which was mainly due to the increase in temperature from year to year. The farmers experienced repeated heat wave from day to day and this was getting worse year after year. The change in temperature caused the evaporation of water in the farms which eventually resulted in drought condition. This is illustrated in the following interview remark by one of the farmers:

"There is a huge different in winter and summer season nowadays as compared to the previous year's. Of late, it gets too old and too hot when it is not supposed to be. We don't even know when summer is and when it is winter"

Another 69-year-old female farmer pointed out that:

"Cold season used to start in May or early June. It was common to find water inside the house roofing and water on the grass but it is no longer common because winter season are no longer cold as compared to the years when we were still young".

"The farm is currently dry. There is no water on ground and when we irrigate the water just evaporates so fast leaving the farm dry. There is no rain at all which makes our maize so difficult to produce well"

The study by Gbetibouo (2009) in the study conducted in Limpopo Basin, South Africa to understand farmer's perception and adaptation to climate change and variability found that 95% of the farmers experienced long term change in temperature. Another study by Maponya *et al.* (2012) found that 54% of the famers in Limpopo province observed a change in temperature. DeWit (2006) also added that farmers in Southern Africa reported that summer periods are getting hotter and hotter while winter periods are becoming drier and colder. These authors' findings are in line with the findings from the analysis from the SAWS data and the narratives from the farmers.

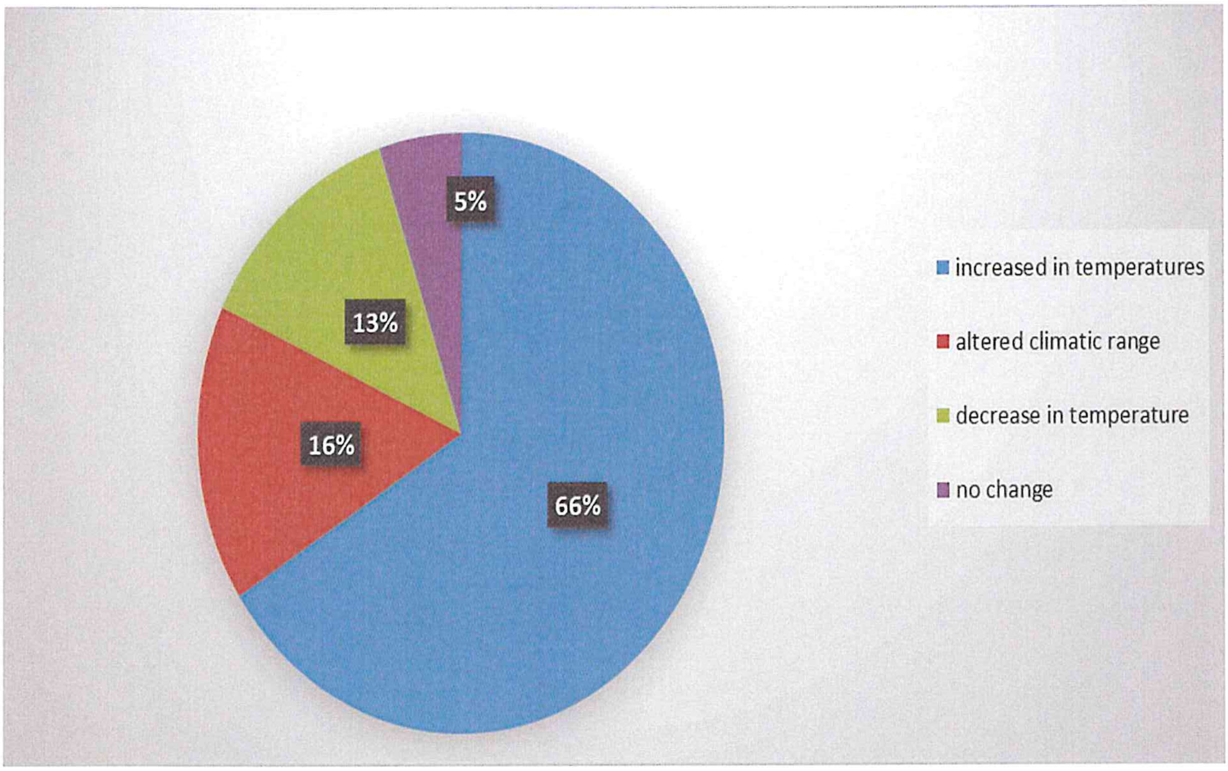

Figure 4.12: Farmers narratives on temperature change (Source: Field survey, 2016)

4.5 FARMERS NARRATIVES ON CHANGES IN RAINFALL IN CAPRICORN DISTRICT MUNICIPALITY

Figure 4.13 indicates farmer's observation in rainfall variability. The overall observations on the change in rainfall indicate that 93% of the farmers from the study area experienced changes in rainfall from year to year. Out of the 93%, 21% indicated that rainfall was decreasing while 11% of them indicated they experienced an increase. 9% of the respondents indicated an increase in the occurrence and frequency of extreme events such as of droughts and floods. 7% of the respondents indicated no change in rainfall.

52% of the farmers indicated a shift in rainfall periods. They said that rainfall either came too early or too late than expected. They further indicated that the region received winter rainfall, which to them was unusual and not useful because maize is not a winter crop. They also indicated that sometimes when it rained they experienced flash floods leading to the damaging of crops especially the seedlings.

One 57-year old male farmer eluded that:

"" There is rainfall but it only rains on other areas. So, we are struggling in a way that our land become dry and we cannot start planting"

About 9% of the respondents noticed an increase in frequency and intensity of drought and floods condition. According to one the farmers, this was mainly due to shortage of rainfall and increasing temperature. This is in line with the findings of DeWit (2006) who found that farmers in Southern Africa also reported delayed in rainfall, with rainfall either coming earlier or later than expected.

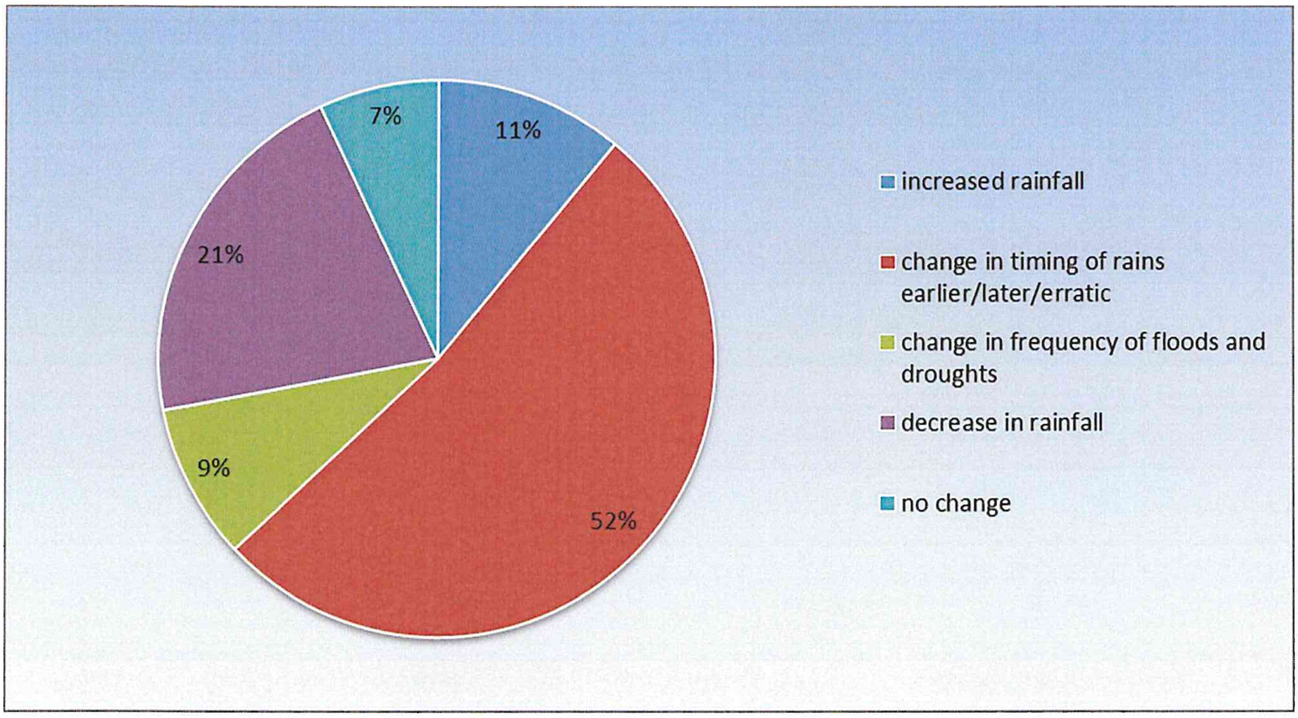

Figure 4.13: Farmers narratives on rainfall changes (Source: Field survey, 2016)

4.6 THE EFFECTS OF TEMPERATURE AND RAINFALL VARIABILITY ON SMALLHOLDER MAIZE FARMERS

Increased temperature resulted in high evaporation leading to loss of soil moisture in farms. From the study, 9% of the maize famers reported the loss of soil moisture in their farms has caused the drying out of maize before they could mature. Cresser *et al.* (2008) established that high temperature resulted in reduced or loss soil moisture leading to reduced maize yields in China and further south in Eastern Asia. Another study by Cline (2008) conducted in the south-western Zimbabwe to establish the effects of drought on corn found that higher temperatures also interfered with the ability of plants to get and use moisture because evaporation from the soil accelerates when temperatures rises and plants increase transpiration. That resulted in the loss of soil moisture from their leaves leading reduced and loss yield (Cline, 2008).

Higher temperature accelerated maize maturing which subsequently reduced yields. This was indicated by 1% of the farmers that maize dry out before they could reach maturity. This is in line with the findings by Collaku and Harrison (2002) who argued that higher temperature results in change in gain filling duration. The author continued that heat wave limits the amount of time the plants need to convert to starch and fill grain. The European heat wave of 2003, when the temperature were 6°C, crops yields dropped by 36% for maize in Italy due (FAO, 2008).

High temperature associated with changing precipitation has resulted in the increase in type and occurrence of insects, pests and disease as experienced by 21% %of the respondents. Farmers interviewed indicated that increased temperature has led increase of black of spots on maize stalk and ear, pests such as worm, ants, birds and caterpillars. The worms has caused the seed not to germinate well, birds and caterpillars attacks the stalk and ear of the maize which leads to low maize production. According to Anderson *et al.* (2006), increased temperature alters the abundance and types of many pests, lengthen pests' breeding season, and increase pathogen growth rates in crops. The study by Morton (2007) found that Maize Streak Virus and Cassava Mosaic Virus are found in areas where rainfall increases, and sorghum head smut (fungal disease) in areas where rainfall decreases. Farmers in Philippines reported a number of climate change abnormalities such as pests and diseases in rice, corn and fruits trees due to excessive rainfall (Lasco *et al., 2011).* Another study by Ndambiri *et al.* (2013) found that humidity influences the prevalence of diseases-causing vectors in Kenya.

Decreased temperature during winter has led to poor germination of maize. The respondents (5%) have reported that there has been an increase in the occurrence of frost in maize mainly due to low temperatures. Farmers reported that maize don't germinate well mainly due to reduced temperatures and frost. Maize seedling rots in soil before they could reach geminate. Besides maize seedlings to rotting in soil, some of the seedlings have already beginning to suffer. Similar effects has happen in UN 2007 where the freeze has caused a widespread devastation on crops because frost occurred during flowering period, germination period and early grain development (Karl, 2009). Walthall *et al.* (2012), mid-winter temperature of between 10°C and 0°C in Califonia lead to early bud-burst or bloom of some perennial plants, resulting in frost damage when cold winter temperatures return.

Table: 4.1: Effects of temperature and rainfall on smallholder maize farmers (**N=253)**

Variables	Percentage (%)
Loss of soil moisture	9
Drying out of maize	1
Increase in pests, insects and diseases	21
Poor germination	5
Increase in invader plants	19
Reduced yield	18
Change in growing season	16
Waterlogging	10

(Source: Field survey, 2016)

Heavy rainfall associated with higher temperature has resulted in the increase of invader weeds in the farm. According to the study, 19% farmers have perceived that the invader weeds have been occurring since they started maize production. Currently, most of the farmers are losing their maize to weeds which leads to low productivity in maize. According to Blignaut *et al.* (2009), crop yield and quality are affected by weeds growing among crop plants, thereby causing high crop losses. The warmer temperature resulted in the loss of soybean and corn in the southern Gulf States, United State to a very aggressive weed species such prickly sida and

Johnson grass (Karl, 2009) also added that in United State, southern farmers lost 64% of the soybeans crop to weed while the northern farmers' lost 22%.

The study revealed that 10% of the respondents experienced waterlogging of maize in their farms mainly due to heavy rainfall leading to floods. The changes in timing, intensity and the amount of rainfall has resulted in maize being submerged in water and eroded leading to low crop yield and death. The study by Collaku and Harrison (2002) indicated that rains delay plantings, growing and harvests, and rains prior to harvest can cause pre-harvest sprouting, which lowers yield but more importantly, reduces grain quality. Waterlogging reduced wheat yields 20% to 50% in United State (Collaku and Harrison, 2002). Another study by Adams *et al.* (1998) also found that large areas of Latin America are affected by extreme events such as heavy rainfall leading to floods which resulted in reduced crop yield of between 10% and 30%.

Based on the maize farmers responds, it was reported that 18% of the smallholder maize farmers are experiencing change in timing of rainfall, delays, earlier and erratic rainfall. Rainfall come earlier than usual and it comes late unexpected. This has led to smallholder maize farmers in the district not knowing the exact time to start planting. So farmers were forced were forced to start replanting since their maize did not germinate. Some of the farms were left uncultivated due to late onset of the main rainy season. These finding are also supported by Mary *et al.* (2009) in Tanzania indicated that delays in rainfall, unexpected rainfall has led to poor germination of seeds requiring farmers to undergo multiple sowing of seeds. In United State, excessive water during corn's early growth stages caused a reduction in growth and even death, while soil water deficit led to less growth and lower yields when the stress occurs during the grain filling period of growth (Walthall *et al.*, 2012).

Smallholder maize farmers (16%) in the study area have noticed the change in growing season on maize production. Maize was found to be taking long time to mature which also resulted in change in harvesting season mainly due to change in temperature. The study by Diaz-Ambrona *et al.* (2013) indicated that maize maturity reached 17 days earlier in Zamorano and 11 days earlier in Comayagua and la Esperanza. In future it is predicted to a reduction of 3 to 20 days from sowing to crop maturity (Diaz-Ambrona *et al.*, 2013). Another study conducted in Europe, established global warming has extended the length of the potential growing season, allowing earlier planting of crops in the spring and earlier maturation and harvesting (Olesen *et al.,* 2002). Thornton *et al.* (2003) also added that the length of the growing period reduced by more than 20% due to higher temperature and the season failure rate increase as frequently in Latin America.

4.7 Conclusion

Among many elements of weather and climate in Capricorn District Municipality, rainfall and temperature are the most common and important for the rural peoples' livelihoods that depend on rain-fed agriculture. Throughout the study period, it was established that maximum temperature have increase and shorter during winter. The minimum temperature has fluctuated and varied with the highest month in January and decreasing from year to year. The rainfall pattern in Capricorn District Municipality indicated that rainfall is scarce and trend varied with no obvious pattern. The highest rainfall experienced was in April 1994 and lowest in August 2011 and the trend indicated that in the district is decreasing. The highest rainy days was observed in November 2001 and 2006 but in 2002 there was no rainfall the whole month. This indicated that there was an incident of drought condition in the study area. The number of rainy in days during summer season has extended to autumn with the highest peak in April 2007 and March 2012. During winter the highest peak was in June 2000 which was unusual. The highest rainfall days was also experienced in August which is unusual because Capricorn District Municipality experiences a summer rainfall from November until March.

The highest rain free days was experienced in 1993 and 2011 ranging from 23 and 22.8. The greatest decrease was in 1998 by 21, 5 to 14.4 rain free days. From the analysis of SAWS data, it was established, although not highly significant, that there were changes in temperature and rainfall in Capricorn District Municipality. 95% of the farmers interviewed also attested that they have experienced the change in temperature. 16% of the farmers experienced alteration in seasons where the winter seasons have become longer than usual. 93% of the farmers interviewed indicated a change in rainfall patterns, where 21% of them experienced a decrease in rainfall, 11% indicated an increase in rainfall, 9% of the farmers experienced an increase in extreme events such as drought and floods and 7% experienced no change in rainfall.

Most farmers (21%) indicated that due to an increase in temperature, there has been an increase in the incidents of pests. Besides increasing pests, there was a loss of soil moisture in farm as reported by farmers (9%) which reduced productivity. The farmers noticed changes in growing season. Due to heavy rainfall and associated floods, farmers noticed that maize plants become submerged in water and also waterlogged. There was also an increase in development of invader weeds. The unknown timing of rainfall has resulted in some farms uncultivated and also decreased in maize yields.

CHAPTER 5
SMALLHOLDER MAIZE FARMERS ADAPTATION TO TEMPERATURE AND RAINALL CHANGES

5.1. INTRODUCTION

Climate has changed and is changing and will continue to change. Based on that, smallholder farmers are highly vulnerable to extreme climate variable since they are weather dependent. Smallholder farmers already face numerous risks to their agricultural production including the increase in pests and disease outbreak, increase in frequency and severity of floods and drought, poor yield, crop failure, low crop productivity (Harvey *et al.*, 2014). According to Benedicta *et al.* (2010), the main adaptation strategies of farmers in Sekyedumase District in Ghana include change in crop types, planting short season varieties, changing planting dates and crop diversification. According to Sekaleli and Sebusi (2013), farmer's adaptation strategies in Lesotho include water harvesting technologies, conservation tillage, use of keyhole and trench gardens, agro-forestry and application of traditional medicine to control pests and diseases. In china, farmers have implemented their own adaptation strategies, such as changing cropping patterns, increasing investment in irrigation infrastructure, using water saving technologies and planting new crop varieties to increase resistance to climatic shocks (Wang *et al.*, 2010).

Farmers appear to be well aware of climate change and few seem to actively take steps toward adjusting their farming activities. The smallholder maize farmers in Capricorn District Municipality have been responding to climate variability through various strategies. However, the most preferable strategies employed by smallholder farmers in the district include: mulching, change in planting dates, use of manure, use of fertilisers, crop rotation, use of pesticides, weeding, furrows, compost, irrigation, use of traditional methods such as burning of pests, use of traditional indicator, early harvest, use of chemicals and use of ashes. However, these adaptation strategies employed by the smallholder maize farmers are influenced by the socio-economic and institutional factors such as gender, age, non-farm income, occupation, household size, extension, climate information, finance, number of years in agricultural practice and farm income.

5.2 SMALLHOLDER MAIZE FARMER'S ADAPTATION ON TEMPERATURE AND RAINFALL IN CAPRICORN DISTRICT MUNICIPALITY

Lack of rainfall together with high temperature can also accelerate the rate at which drought condition occur where by soil can end up causing the loss of soil moisture and soil fertility. During the plantation of maize, the seed could not germinate due drought and those that germinate ended up drying. Due to drying out of maize because of lack of rainfall and increased temperature, maize farmers have adopted to strategies to cope such as mulching, irrigation, manure and traditional indicators. Smallholder maize farmers (9%) sometimes use traditional methods as an indicator for possible rainfall. For example, when the clouds are too dark, it's a sign that indicates that rain is coming. The direction of the rain and strong wind accompanied by dark clouds are also been used as indicators. These findings are supported by Maponya *et al.* (2012) and Ojwang' *et al.* (2010) that a change in wind direction or formation of dark clouds is a precursor to the coming of rains and this acts as a warning to trigger land preparation. Manyeruke *at al.* (2013) added that Due to the absence of proper extension services to farmers, many farmers have kept up with their traditional farming practices which are no longer suitable taking into account the unpredictability of rainfall patterns.

Due to lack of rainfall, (5%) have adopted mulching system as one the strategies to cope. Mulching was very important as it prevents maize seedlings from harsh environment. During mulching, respondents make use of dry maize, leaves, sawdust and grass which suppresses weed growth and reduces the amount of water that evaporates from the soil. According to Maponya *et al.* (2012), mulching improves the quality of the soil by breaking up clay, allowing better movement of water and air through the soil. Mulching system conserve soil moisture, flooding and down climate variability such as high temperature and shortage of rainfall. Benhin (2004) added that mulching cools the soil surface and stabilize soil temperature. Another study by Enete *et el.* (2011) conducted in Nigeria on indigenous agricultural adaptation to climate change concluded that increasing the use of organic matters such as mulch could prevent excessive soil moisture loss, increase soil aeration and soil moisture holding capacity.

34% of the respondents irrigate their maize due to lack of rainfall and high temperatures. Irrigation systems have also been used by smallholder maize farmers to cope against drought. Due to high temperature which leads to high evaporation of moisture, farmers prefer to irrigate in the morning and afternoon. Another farmer added that they have their own boreholes in farms and make use of sprinkles to avoid soil erosion and to save water. According to Benhin (2004), some of the famers have shifted from flood irrigation to sprinkler irrigation for wise use of water. The irrigated farms have higher maize yields than did dry land farms. Maize yields are determined more by the level of precipitation than by the presence of irrigation, indicating that irrigation practices partially mitigate the impact of decreased precipitation on yields (Akpalu *et al.*, 2009).

Smallholder maize farmers make use of manure to adapt to higher temperature and shortage of rainfall. As indicated in Table 6.1, 13% of the farmers prefer to use manure before they could start planting and when have already planted. Famers make use manure and artificial manure. Manure holds moisture and prevents maize from drying out. Manure was found to be mainly in the form of crops residues usually from cereals. The use of manure by smallholder farmers is perceived to be effective and less costly in terms of improving soil moisture as a result of extreme weather events in Northern Ghana (Etwire *et al.*, 2013). According to the study by Benhin (2004), higher temperature and evapotranspiration, farmers have resorted to increase the application of chemicals such Erian to reduce evapotranspiration and also apply more manure to keep the moisture content of the soil higher.

Heavy rainfall leading to floods which resulted in reduced crop yield. Farmers (46%) have adapted to rainwater harvesting such as water channel and making furrows to prevent the crops from being eroded. According to one of the famers, they channelling water saves and do not irrigate during that time. Water harvesting during heavy rainfall was also been used as an adaptation strategy. During rainy season, farmers store water in tanks and container so that the water can be used during shortage of rainfall. Juana *et al.* (2013) added that in southern Africa and parts of East Africa, where most countries are water flooded, farmers have developed water conservation methods such as water harvesting, waste water re-use in agriculture and crop irrigation. According to Maponya *et al.* (2012), this practice store available rainwater during the wet season and also to use the water for crop irrigation in the dry season. This has achieved excellent results especial in some dry parts of Limpopo province. The study by African Technology Policy Studies Network (2013) drought prone areas in Lesotho, farmers use roof water harvesting technology to collect water and store it in stone built-tanks next to their houses and this is used for watering crops in the garden as well as for household use.

Heavy rainfall and associated flood have resulted in the loss of soil fertility leading to erosion which has caused an increase in runoff of fertile soil and leaching of agricultural chemical and decrease of soil moisture and nutrients. According to the study by FAO (2007) on the adaptation to climate change in agriculture, forestry and fisheries concluded that the key element to increase the soil fertility is to improve soil organic matter. And can be done by stabilizing the soil structure so that soil absorbs enough amount of water required. Most of the smallholder maize farmers in the district prefer to use compost (34%) such as cow dung, chicken faeces and dried maize as a way to improve the soil nutrients and fertility. African Technology Policy Studies Network (2013) further added that farmers with livestock, especially cattle, use cow-dung instead of inorganic fertilizers when they plan to add fertility to the soil. About 15% of the respondents used of fertilisers to enhance quick release of nutrients. Organic matter allows the soil to absorb enough water during extended floods and drought. According Enete to *et al.* (2011), high fertilizer application is therefore expected as an adaptation practice in order to maintain soil fertility.

The increase in temperature and heavy rainfall has resulted in the increase in pests, insects and diseases. The famers have been facing changes in the number, types and frequency of pests, diseases and weeds. As indicated in Table 5.1, 52% smallholder maize farmers have used different methods in order to cope with the increase in pests and diseases. The respondents have identified the following adaptation strategies such pesticide (40%) to spray on maize, early harvest (12%) to avoid the maize from being damaged and crop rotation (17%). The use of pesticides through the adoption of integrated pest management systems, which targets the control measures to the observed problem (Olesen *et al.*, 2002). Due to the increase in the presence of pests, spraying is already much common. The study by Rosenzweig *et al.* (2001) conducted in U.S. Midwest concluded approximately 3.2 million hectares were sprayed with insecticides to control the mites across the region. Early harvest was reported by farmers (12%) to reduce the attack of pests and disease on plants. They either planted early or late as an indigenous adaptation mechanism to climate change and variability (Etwire *et al.*, 2013). According to Lasco *et al.* (2011), the change in cropping calendar is one of the adaptation strategies that farmers use to adapt to climate change. It involves altering the timing of farm activity to suit the climatic variation. Most of the farmers (17%) prefer crop rotation and as they increase the nutrient content, reduces disease, insects and pests. This findings is supported by Maponya *et al.* (2012) that crop rotation contributes to diversification of crop species and decreases the of diseases and pests attack.

Due to the increase in the development of weeds, 34% of the famers adopted to weeding as one their adaptation strategies. Etwire *et al.* (2013) added that early and regular weeding is being used as the most effective way of dealing with the effects of climate change and variability. Early and regular weeding is perceived to be effective in dealing with the emergence of stubborn weeds.

5.3 DETERMINANTS OF FARMER'S CHOICE OF ADAPTATION STRATEGIES TO TEMPERATURE AND RAINFALL CHANGES

The gender of the farmers had a significant positive relationship with change in planting season, use of manure adopting conservation agricultural techniques (mulching, crop rotation and use of furrow irrigation), and irrigating and weeding their farms – change in planting season ($P<0.01$), conservation agricultural techniques ($P<0.01$), use of manure ($P<0.10$), irrigation ($P<0.01$), and weeding ($P<0.01$). Male farmers had higher probability of changing planting season, conservation agricultural techniques, use of manure, irrigation and weeding. Deressa *et al.* (2009) in their study conducted in Nile Basin of Ethiopia where they analysed factors that affected the choice of coping strategies for climate extreme found male farmers were flexible and were able to pull up their labour forces in irrigation, weeding and conservation agricultural techniques. The other probable reason the authors found was that farming activities were done by males while female farmers were involved in household activities. This gave male farmers opportunities to implement better adaptation strategies related to climate change and variability because they were hands-on in the farm.

Nhemachena *et al.* (2008) added that women were less able to diversify income sources and adapt to climate change because of their domestic responsibility and less control of financial resource. Temesgen *et al.* (2014) added that male headed household are often considered to be more likely to get information about new technology and take on risks than female headed household. However, Nhemachena and Hassan (2007) disagreed that female headed households were more likely to take up adaptation options to climate change and variability since much of the agricultural work is done by women.

The age of the respondents had a statistical negative relationship to crop [rotation practices, use of manure, and weeding their farms – crop rotation practices ($P<0$, 01), use of manure ($P<0.05$) and weeding ($P<0.05$). An increase in age of farmers decreased the use of crop rotation practices, use of manure and weeding. Tazeze *et al.* (2012) argued that older farmers are used to farming in a traditional way and were not interested in changes, and younger farmers were more excited and willing to adopt new methods in their farming. Gbetibouo *et al.* (2009) also added that older people are less willing to take up risks associated with new technology and climate extreme compared to young farmers.

Farmers' highest level of education had a significant positive relationship with the use of manure, and changing planting season. Therefore, educated farmers are more able to notice the changing climate and choose better adaptation strategies. The survey established that education level of the household head had a positive influence in the use of manure ($P<0.01$) and changes in the planting dates ($P<0.10$). This implies that farmers with higher level of education are more likely to adopt these measures when addressing effects of rainfall and temperature variability. According to Uddin *et al.* (2014), educated farmers have more knowledge and ability to understand and respond to changes, forecast future scenario and have access to information and opportunities to encourage better adaptation strategies. Deressa *et al.* (2009) added that the level of education increases soil conservation and changing planting dates as an adaptation method. The authors further argued that a unit increase in number of years of schooling resulted in a 1% increase in the probability of soil conservation and a 0.6% increase in change in planting dates to adapt to climate change.

The size of the household was found to be positively related to change in planting season, and irrigating and weeding the farms – change in planting season ($P<0.01$), irrigation ($P<0.01$) and weeding ($P<0.05$). Farmers with larger households change planting season according to change in rainfall and temperatures, irrigated their farms and practiced weeding. Deressa *et al.* (2009), argued that large family size was with higher labour endowment that enabled them to accomplish various agricultural tasks and adaptation measures. This view is also shared by Deressa *et al.* (2009) who argued that large family size associated with a higher labour endowment, enabled households to accomplish various agricultural tasks.

The results from the Multinomial logistic regression model shows that access extension services has a positive significant relationship with the conservation agriculture technique use of manure and irrigation-conservation agriculture technique ($P<0.05$), use of manure ($P<0.01$), and irrigation ($P<0.01$). Therefore, farmers with access to extension services are likely to adapt to conservation agriculture technique use of manure and irrigation than smallholder maize farmers with no contact access to extension services. The possible reason for this positive relationship is due to the fact that farmers who have access to extension services are more likely to be aware of the changes climate conditions as well as have the knowledge of different management practice that they could adopt when necessary. According to Manyeruke *et al.* (2013), agricultural extension services to advice farmers on what crops to grow, when to grow these crops and where to grow them. The study by Tazeze *et al.* (2012) found that extension services influences decision of farmers to use one of adaptation option or to cope with another adverse impact of climate change and variability. According to Salau *et al.* (2012), frequent contact with extension agents also increases the probability of taking up adaptation measures because farmers who have significant extension contacts have better chances of to be aware of changing climatic conditions and management practices they can use to adapt to climate change. According to Deressa *et al.* (2009), and Gbetibouo (2009) farmers who have significant extension contacts have better chances of being aware of changing climatic conditions as well as adaptation measures in response to the changes in these conditions. Nhemachena and Hassan (2007) added that farmers who have extension contacts have better chances to be aware of changing climatic conditions and also of the various management practices that they can use to adapt to changes in climate condition.

Access to climate information had a positive significant influence on the likelihood of using irrigation and weeding - irrigation ($P<0.05$) and weeding ($p<0.10$) as an adaptation strategy to temperature and rainfall variability. Deressa *et al.* (2009) and Obayelu *et al.* (2014) found that getting climate information from sources such as radios, television, newspaper on daily basis, seasonal forecast and climate variability helps the smallholder maize farmers to make comparative decision amongst available adaptation practices and chose the one that were better responsive to changes in temperature and rainfall variability. This implies that farmers with access climate information were more likely to weed and irrigate as compared to those without access to climate information.

Farmers access to finance was found to have a positively significant relationship with change in planting dates conservation agricultural techniques no adaptation use of manure and irrigation - change in planting dates ($P<0.10$), conservation agricultural techniques ($P<0.10$), use of manure ($P<0.10$) and irrigation ($P<0.10$). This implies that access to finance increases the likelihood to choosing of change the planting dates, use of manure and irrigate. According to Nhemachena and Hassan (2007), access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with the various adaptation options they might want to take. For instance, with financial resources and access to markets farmers are able to buy new crop varieties, new irrigation technologies, and other important inputs they may need to change their practices to suit the forecasted and prevailing climatic conditions.

From this study, number of years in agricultural practice have a significant and positively relationship to conservation agricultural resources, crop rotation and weeding -conservation agricultural resources ($P<0.10$), crop rotation ($P<0.01$) and weeding ($P<0.05$). This implies that farmers in the district who have been in farming for long time are likely to be aware of climatic conditions and have knowledge on the management practice they could employ to adapt to the changes in there conditions. Deressa *et al.*(2009) conducted in Ekiti, Nigeria on adaptation to climate change added that number of farming experience has helped farmers in the area to switch from adaptation strategies to another based on the situation of climate variability. This is consistence with findings of Apata (2011) that experienced farmers have higher probability of perceiving climate change as they were exposed to past and presents climate conditions over longer perspective of their times. Salau *et al.* (2012) added that highly experienced farmers are likely to have more information and knowledge on changes in climatic conditions and crop and livestock management practices

The results from the study showed that an increase in farm income of the household increase the likelihood of choosing adaptation strategies such conservation agricultural resources crop rotation and weeding -conservation agricultural techniques ($P<0.10$), use of manure ($P<0.10$), and irrigation ($P<0, 01$). This implies that famers with high income are likely to have better to manure, water for irrigation and be able to conserve water. Farmers with farm income tend to invest on productivity option such as water conservation and crop diversification (Apata, 2011). This is consistence with the finding of Deressa *et al.* (2009) and Tazeze *et al.* (2012).

5.4 CHALLENGES FACING SMALLHOLDER MAIZE FARMERS IN ADAPTING TO CHNAGES IN TEMPERATURE AND RAINFALL IN CAPRICORN DISTRICT MUNICIPALITY

Table 5.1, it is indicated that 25% of the respondents lack access to equipment and new technology. Most of the maize farmer's responded that lacks equipment's such as irrigation pipes, sprinkler and bore-hole, mechanisation and protective structure such as safety nets to guard against extreme events. According to FAO (1996), poor irrigation potential can most probably be associated with the inability of farmers to use the already existing water due to technological incapability. Most farmers from developing countries are resource poor and cannot afford to invest on irrigation technology to adapt to climate change in order to sustain their livelihood during harsh climate extremes such as drought which often causes famine. According to Ngigi (2009), lack of technology has a serious problem to smallholder farmers as it limits smallholder farmers their ability to implement adaptation strategies.

According to Gbetibouo (2009), access to financial resources such as funds, credits play a vital role on smallholder farmers as it enables farmers to adapt during abrupt changes in temperature and rainfall. Zwane *et al.* (2016) added that having insurance can build financial resilience as it helps farmers' access credit assistance more easily, allowing them to innovate and invest in technologies that boost productivity.

From Table 5.1, 19% of the smallholder respondents in Capricorn District Municipality lack access to financial resources such as funds. They indicated that they did not have means to access loans from commercial banks and agricultural funding institutions because they did not have the required collaterals. This indicates that most of smallholder farmers are unable to purchase proper machinery or develop proper infrastructure. These farmers could also not buy high yield seeds and fertilizers associated to enhance their production. According to Binns (2012), formal insurance is difficult to obtain because it requires upfront sums of money before the harvest that most farmers do not have, it requires a level of financial literacy that they often do not have. Adaptation to climate change is costly (Mendelson, 2004) and this cost could be revealed through the need for intensive labour use. Thus, if farmers do not have sufficient family labour or the financial capacity to hire labour, they cannot adapt to climate change. The study by Harvey *et al.* (2014), in Madagascar, found that most farmers did not have enough savings to be able to adapt effectively to changes in climate, had no developed insurance markets and instead rely on informal support systems, borrowing money from family or friends. The study by Wilk *et al.* (2012), on the adaptation to climate change and other stressors among commercial and small-scale South African farmers, added that small-scale farmers expressed that lack of finance made them unable to buy machinery and implements for tillage, planting, harvesting and controlling fire through the burning of firebreaks. Binns (2012) also added that an increase in the effects of climate change and variability increased in use of herbicides and pesticides and hinders the financing for farmers as herbicides and pesticides is a financial burden on the household.

One of the Farmers complained that:

'Lack of money is a challenge to us. We need money to buy inputs and prepare for the new farming season'

Table 5.1 indicates that 18% of the respondents have no access to reliable climate information. Due to abrupt increase in extreme weather events such as floods and droughts, farmers are left with no time to adapt because the smallholder farmers do not have skills, knowledge and information on climate in order to adapt (Action aid, 2006). For instance, lack of information to adaptation options could be attributed to the fact that research on climate change and adaptation options have not been strengthened and information is lacking. According to Wilk *et al.* (2012), adaptation to climate change and other stressors among commercial and small scale in South Africa found that farming acknowledged the importance of knowledge passed down from elders, but also stressed that knowledge continually needs updating such as new techniques, equipment, breeding practices, crop varieties and pesticides. For many practices, the biggest barrier is knowledge, because activities such as composting, mulching, rotating crops, or letting fields or strips lie fallow do not usually require any extra materials, they just require the expertise to implement them, which can be learned from an extension agent (Binns, 2012). The small-scale farmers relied exclusively on advice from the extension office, with insufficient resources to provide adequate support. The farmers mentioned that knowledge was not only needed about agricultural practices but also on budgeting and farm finance, in order to be able to plan and maximize profits. So lack of reliable information unable the farmers to have proper adaptation strategies and also to make rational decision on their maize production. Most of the smallholder farmers rely on climate information from media such as television, radios and newspaper and which is not sometimes reliable and useful to them. This is illustrated in the following interview remark:

"I rely mostly on television for weather. Sometimes it might say that there will be 30% of rainfall in Polokwane the whole week. But only to find that there is no, even single drop of rainfall. By that, we don't know when to expect rainfall and when to start farming'

According to FAO (2001), even when the climate information was provided, it comes in a form of seasonal forecasts that may not be useful to a long term climate planning. Information and awareness could serve as barrier to successful implementation of agricultural practice. The study by Binns (2012) on opportunities and challenges facing farmers in transitioning to a green economy agriculture practice concluded that as simple as having a rain gauge on the farm allowed farmers to manage their crops better and get better yields. Harvey *et al.* (2014) concluded that having access to agro meteorological or market information, could help inform farm management decisions, such as the choice of crops, planting dates and management strategies, and which could serve as early warning systems for floods and cyclones.

Table 5.1: Constraints faced by smallholder farmers in adapting to changes in temperature and rainfall (N=253)

Variable	Percentage (%)
Inadequate funding	19
Unreliable climate information	18
Inadequate access to extension service	4
Lack of inputs	22
Lack of adequate road and infrastructure	6
Poor access to technology and equipment's	25
Did not experience any challenge	7

(Source: Field survey, 2016)

Table 5.1 indicates that only 4% of the respondents do not have access to extension services. Farmers who have access to extension services indicated that the information that they got its not helpful and relevant. Sometimes the information provided by the extension officer comes late when the information is no longer helpful. According to Gbetibouo (2009), most of the smallholder farmers lack information from extension officers such as workshops and trainings and that has caused major constraints. Roncoli *et al.* (2010) added that poor quality of government services such as lack of relevant knowledge and commitment by extension agents and unreliable predictions by the meteorological Department, farmers invested more than usual in farming expectation of abundant precipitation which did not materialize and their maize crop was drying in the fields. Another study by Benhin (2014) conducted in South Africa found that farmers with limited extension services asserted that the information provided is not helpful and not relevant to mitigate the effects of climate change (Benhin, 2004).

Lack of agricultural inputs to smallholder farmers has made unable to adapt to the change in temperature and rainfall. As indicated in Table 5.1, 22% of the respondents lack agricultural inputs such manure, fertilisers, irrigation water, pesticides and proper maize seeds to adapt to changes in weather condition. Due to that, most of the smallholder famers are unable to mitigate against the effects of temperature and rainfall variability. The study by Wilk *et al.* (2012) on the adaptation to climate change and other stressors among commercial and small-scale South African farmers argued that the improved seed varieties that they purchased annually were considered costly. Makondo *et al.* (2014) also added that inputs such as seed and fertilizers are delivered late and when they are delivered, they are available at costs usually beyond the reach of average rural farmers.

6% of the farmers lack proper roads and other agricultural infrastructure. The road in rural area becomes impassable during rainy season which prevents them from accessing inputs in the market and selling their crop to the nearby village. This is the illustrated in the following interview remark by one of the farmer:

"I harvest more enough so that I can sell and buy inputs for the next season, but because we don't have proper markets in the area, the maize become spoiled, dry and I end up throwing them away which is a waste to me"

Another farmer also added that:

"Since we don't have supermarkets in the like Shoprite and Spar, we end up selling at a giveaway prices to the local businessmen who sell to millers and supermarkets' in the cities at a better price"

Another farmer also added that:

"The roads in the area are impassable, delivery transports cannot pass during rainy season"

The study by Harvey *et al.* (2014) on extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar indicated that factor that increases farmer vulnerability is the remoteness of farm villages and lack of adequate road infrastructure. The roads are in a poor state and unevenly distributed, with many villages lacking roads that connect them to other villages and the main roads are often accessible only during the dry season. Zwane *et al.* (2016) also added that men and women in Garissa complained about the poor state of the roads, which become impassable during the rainy seasons. Roncoli *et al.* (2010) on adaptation to climate change for smallholder agriculture in Kenya also argued that poor road infrastructure has hindered movements and the flow of farm produces to markets, and in-put requirements such as seed and fertilizers to farmers.

According to DAFF (2012) majority of smallholder farmers in South Africa receive low prices for their products by selling them at their farm gate or local markets. However, the report argued that these smallholder farmers could receive much higher prices by selling their goods by using marketing knowledge and selling skills as well as little recognition of opportunities for product diversification or the limits between market research and product development.

5.5 CONCLUSION

The main adaptation strategies employed by smallholder maize farmers in Capricorn District Municipality are mulching, irrigation, use of manure, weeding, change in crop varieties, change in planting dates, crop rotation, use of pesticides, use of fertilisers, use of compost, use of chemicals, make furrows, and the use of traditional methods such burning of pests. Age, gender, occupation, household size, access to finance, access to extension service, number of years in farming, strongly influence the choice of adaptation strategies. For example, *age* of the respondents was found to be negatively relative to crop rotation practices, use of manure, and weeding their farms because an increase in age of farmers decreased the use of crop rotation practices, use of manure and weeding.it was also found that number of years in agricultural practice have a significant and positively relationship to conservation agricultural resources, crop rotation and weeding implying that farmers in the district who have been in farming for long time are likely to be aware of climatic conditions and have knowledge on the management practice they could employ to adapt to the changes in climate.

Majority of smallholder maize farmers in Capricorn District Municipality were willing to adapt to changes in temperature and rainfall but were constrained by many factors. 25% have poor access to technology and equipment's as the main barriers to adaptation, 22% of the household do not have access to agricultural inputs such as irrigation water, manure, fertilizer, pesticides and tractor. Lack of inadequate funds (19%) and unreliable climate information (18%) are also indicated by the smallholder farmer as significant barriers to adjustments. Few farmers 4% designated inadequate access to extension services of appropriate adaptation measures as barriers to adaptations. About 6% of the farmers were constrained by lack of inadequate road infrastructure with prevented them from access and transferring agricultural products to other village. Improving access to technology, funds, agricultural inputs, extension service and increasing communication within and across the farming communities through knowledge sharing forums are concrete means to support and encourage small- scale farmers to improve their farming operations.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The study was intended to analyse changes in temperature and rainfall and associated effects on smallholder maize farmers and adaptation measures together with factors influencing the choice of adaptation strategies. The first objective was to assess the changes in temperature and rainfall in the district between 1993 and 2013. The second objective was to assess the effects of changes in temperature and rainfall on smallholder maize farmers in Capricorn District Municipality. The third objective was to profile maize farmers' adaptation strategies and the factors influencing the choice of adaptation method.

6.2 SUMMARY OF KEY FINDINGS IN RELATION TO THE OBJECTIVES

6.2.1 The impacts of temperature and rainfall changes on smallholder maize production

The statistical analysis of temperature data from 1993 to 2013 in the Capricorn District Municipality shows a trend of increasing, with the increase mostly in the summer and winter period. Over the 20 years, rainfall is characterized by large annual variability with a substantial decrease in the amount of rainfall during rainy season. However, there is a noticeable, long-running trend of decreasing rainfall during winter. According to the linear regression trend analysis test, the maximum temperatures indicated an increase of 0.0131°C in a year while minimum temperatures decreased by 0,024°C in a year. Looking at the linear regression of rainfall, indicated that for a period of 20 years' rainfall deceased by 0.02 in year. The rainfall anomalies confirmed that the drought condition and rainy days are also changing from year to year.

Majority of the farmers noted that there was an increase in temperature, extended periods of temperature, a decrease in precipitation, changes in the timing of rains and an increase in the frequency of droughts. Farmers' narratives on changes in temperature and rainfall are in line with analysis of climatic data records from South African Weather Service. Indeed, farmers in Capricorn District Municipality are able to recognize that temperatures have increased and there was a reduction in the amount of rainfall.

Agriculture has proved to be extremely vulnerable to climate change as seen by the drastic decline in agricultural production. Rise in temperature for example helps to grow crops. Increase in temperature extend the length of the potential growing season, allowing earlier planting, early harvesting and opening the possibility of completing two crop cycles in the same season. Other potential impact linked to agriculture include erosion of the top fertile soil leading to loss of soil fertility that is exacerbated by expected increased intensity of rainfall and the crop growth period that is expected to be reduced. Farmers are frequently subjected to extreme weather events, such as higher temperature and rainfall which result in the increase in pests, pathogens and development of fungal diseases, as well as damage to agricultural fields. High temperatures associated with heavy rainfall are being experienced by farmers eventually reducing the yields of desirable crops while encouraging the development weeds. An increase temperature of resulted in the loss of moisture leading to drying out of soil and maize while decreasing maize yield. Decreased temperature associated with frost has led to poor germination of maize where maize seeds and seedling rot in soil and freezing during the flowering period.

6.2.2 Smallholder maize farmers' adaptation to temperature and rainfall changes

Smallholder maize farmers in Capricorn District Municipality were aware of climate change but not all of them. Farmers who are aware of changing temperature and rainfall responded by adapting. Some of the farmers did not adapt due to lack of resources. Those adapting to temperature and rainfall variability were using crop rotation, mulching, irrigation, water-harvesting, changing planting, use of fertilizers, manure, pesticides, weeding, compost, tradition methods, dates as adaptation strategies.

The multinomial logistic regression model was used to examine the determinants of adaptation to climate change and variability. The results from the study also show that the age of the household head, gender, farming experience, education, distance to the nearest market, household size, access to climate change information, access to extension services, access to finance and off farm income and farm income were crucial factors in influencing the likelihood of farmers to adapt to climate change. Similarly, factors such as the age of the household head, gender, occupation of the household, size of the household, farming experience, household size, farm income, access to information on climate change, access to credit, access to extension service, non-farm income and were also found to determine farmers' adaptation to climate change in the district. Any policy aimed at enhancing the adaptive capacity of the farmers in the study area should thus consider making use the factors mentioned afore.

Factors hindering famers from adapting to temperature and rainfall variability is lack access to technology and equipment's. Most of the smallholder farmers remain outside a formal credit or banking system, lack capital and are unable to access credit or loans. In addition, there inadequate access to formal extension service and farmers currently receive any technical support. Farmers are further constrained by having limited access to reliable climate information, which could help inform on climate, farm management decisions, such as the choice of crops, planting dates and management strategies, and which could serve as early warning systems for floods and cyclones. Another factor that increases farmer vulnerability is the remoteness of farm villages and lack of adequate road infrastructure. Many villages are lacking roads that connect them to other villages. Lack of agricultural inputs is the main constraints on smallholder maize farmers in the district.

6.3 RECOMMENDATIONS

- Agriculture extension services should be strengthened by increasing the interaction between smallholder maize farmers and extension officers by providing enough transport to ensure they conduct adequate field visits to farmers.
- Farmers should be equipped with knowledge on climate change, vulnerability and the adaptation of measures to help them in their faming activities.
- Different forms of information could be passed on using various sources such as print and electronic media, agricultural shows and audio and visual aids. Research institutions such as the Agricultural Research Council, South Africa Weather Service and Non-Governmental Organizations could help with the dissemination of facts about climate change.

- Agricultural planning must be in a position to respond to short and long-term changes in climate and maize production.
- Government policies should address the need to support the training of extension officers so that they are given relevant information about climate change awareness and skills required by the farming communities. They should be equipped with the necessary skills to disseminate information in a simple manner that farmers will understand.
- Governments' policies should ensure that farmers have to affordable credit to increase their ability to change climate production strategies in response to the forecasted climate conditions.
- To improve on the existing knowledge on climate change there is the need to conduct further research at local, regional or country levels. The implementation of any climate change policy requires substantial empirical research evidence of the potential costs and benefits of such policy.

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APPENDIX I: Interview guide

Questionnaire for assessing adaptation to temperature and rainfall variability by smallholder maize farmers in Capricorn District Municipality, Limpopo Province, South Africa

Socio-economic factors of farmers

Gender of respondent

Bong ba mofetotodi

1. Male Monna		2. Female Mosadi	

Age of respondent

Mengwaga ya mofetodi

1. <25 yrs		2. 26-35 yrs		3. 36-45 yrs		4. 46-55 yrs		5. 56-65 yrs		6. >65 yrs	

Marital status

Maemo a lenyalo

1. Single Go se nyalwe		2. Married Nyetše		3. Separated Arogane	
4. Divorced Thlalo		5. Widowed Mohlologadi		6. Other (Specify Tše dingwe	

Occupation

Mosebetsi

1. Unemployed Go se šome		2. Labourer (casual worker) Mošumi	
3. Domestic		4. Business owner	

		Mong kgwebo	
5. Civil servant Mošumedi wa mmušo		6. Farmer Molemi	
7. Retired/Pensioner Motsofadi		8. Other (specify)	

Average monthly household income

Tšhelete ka kgwedi R ______________________________

Household size

Badudi ka gae ________________________

Number of labourers'

Nomoro ya bašumi _____________________

Number of years in formal education

Mengwaga ko sekolong

Training in Agriculture

Thlaho go tša puno

1. Yes Ee		2. No. Aowa	

Number of years in agricultural practice

Mengwa go tja puno ______________________________________

Access to finance

Fihlelelo go tša mašeleng

1. Yes Ee		2. No. Aowa	

Access to extension services

Fihlelelo go balemiši

1. Yes Ee		2. No. Aowa	

Access to water for irrigation

Fihlelelo go meets a go nošetša

1. Yes Ee		2. No. Aowa	

Access to climate information

Fihlelelo ka tshedimušo ka leratadima

1. Yes Ee		2. No. Aowa	

Climate Variability Effects

Have you experience variation in rainfall

Maitemogelo mabapi le diphetogo tša dipula

1. Yes Ee		2. No. Aowa	

Explain the variation

Hlalosa di phetogo

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What are the effects associated with rainfall variation on smallholder maize farmers

Diphetogo tša dipula di tšwentše bjang balemipotlama ba mabele

Have you experience variation in temperature

Maitemogelo mabapi le diphetogo tša phišo

1. Yes Ee		2. No. Aowa	

Explain the variation

Hlalosa di phetogo

What are the effects associated with temperature variation on smallholder maize farmers

Diphetogo tša phišo di tšwentše bjang balemipotlama ba mabele

Climate Variability Adaptation strategies

List the techniques/strategies you use to adapt to temperature variability

Efa mekgwa yeo le e šumišago gore mabele a phele ga botse re lebeletše go fetoga ga phišo

List the techniques/strategies you use to adapt to rainfall variability

Efa mekgwa yeo le e šumišago gore mabele a phele ga botse re lebeletše go fetoga ga dipula

Explain the challenges you face in an effort to adapt to rainfall and temperature variability

Dithlohlo tšeo di le thibelang gore le fihlelele dinyakwa go hlokomeleng ga mabele re lebeletše diphetogo tša phišo le dipula

Explain how you are addressing the challenges you have mention above

Thlalosa gore magato afe o a tšeyago go fetšiša dithlohlo

APPENDIX II: Parameter estimates of the multinomial logit model for climate change adaptation decisions

adaptation strategies	variables	B	Std. Error	p-value
changes in planting season	Intercept	20.898	2539.912	0.931
	Gender	3.669	478.768	0.000***
	Age	-18.629	202.671	0.120
	Non-farm income	1.117	501.799	0.970
	Occupation	4.176	112.385	0.100*
	Household size	8.846	88.793	0.101*
	Extension	-34.731	263.084	0.895
	Climate information	-4.758	588.386	0.885
	Finance	5.544	1112.800	0.080*
	Number of years in agricultural practice	3.795	48.984	0.938
	Farm income	2.986	730.069	0.942
conservation agriculture techniques	Intercept	7.319	6502.114	0.891
	Gender	4.255	3538.383	0.001***
	Age	-4.827	325.512	0.464
	Non-farm income	0.701	1239.292	0.560
	Occupation	-7.537	323.924	0.981
	Household size	0.925	432.445	0.926
	Extension	1.181	1651.813	0.039**
	Climate information	-4.516	6156.304	0.971
	Finance	-2.156	1450.693	0.999
	Number of years in agricultural practice	0.048	108.146	0.056*
	Farm income	7.653	1139.627	0.067*

do nothing	Intercept	9.041	2098.581	0.390
	Gender	0.154	477.897	0.817
	Age	-17.296	202.598	0.302
	Non-farm income	0.054	501.793	0.701
	Occupation	1.508	112.613	0.302
	Household size	12.198	88.834	0.801
	Extension	-1.806	263.567	0.000***
	Climate information	-1.924	588.710	0.860
	Finance	0.878	.000	0.000***
	Number of years in agricultural practice	5.191	48.995	0.090*
	Farm income	1.625	730.070	0.940
practicing crop rotation	Intercept	1.248	15055.989	0.981
	Gender	-1.904	1931.326	0.999
	Age	-0.878	636.190	0.000***
	Non-farm income	0.734	646.684	0.962
	Occupation	-13.167	859.284	0.988
	Household size	-3.606	1112.920	0.997
	Extension	-0.586	4218.367	0.119
	Climate information	-15.729	5392.038	0.980
	Finance	9.497	5658.477	0.987
	Number of years in agricultural practice	5.657	305.327	0.003***
	Farm income	0.951	1942.225	0.985
use of manure	Intercept	9.556	1800.851	0.868
	Gender	0.797	477.897	0.050*
	Age	-17.61	202.599	0. 031**
	Non-farm income	-18.865	501.792	0.100*

	Occupation	11.668	112.612	0.005***
	Household size	1.117	88.834	0.892
	Extension	-0.117	263.557	0.000***
	Climate information	-5.740	588.722	0.157
	Finance	6.292	597.268	0.001***
	Number of years in agricultural practice	5.296	48.996	0.914
	Farm income	0.695	730.070	0.095*
irrigation	Intercept	9.944	1800.884	0.868
	Gender	0.943	477.895	0.003***
	Age	-0.530	202.600	0.931
	Non-farm income	0.090	501.793	0.010*
	Occupation	-1.969	112.612	0.845
	Household size	0.474	88.833	0.008***
	Extension	-37.127	263.565	0.006***
	Climate information	1.975	588.715	0.018**
	Finance	6.369	597.271	0.090*
	Number of years in agricultural practice	5.235	48.996	0.000***
	Farm income	5.204	730.067	0.007***
weeding	Intercept	0.152	3716.892	0.600
	Gender	0.199	1508.724	0.035**
	Age	-0.378	339.629	0.029**
	Non-farm income	3.312	491.797	0.052**
	Occupation	-0.720	291.039	0.327
	Household size	0.351	239.036	0.034**
	Extension	-1.936	1024.056	0.028***

Climate information		8.760	1529.523	0.094*
Finance		13.905	1285.483	0.710
Number of years in agricultural practice		1.777	82.920	0.017**
Farm income		0.620	1674.998	0.477

Base category: use of pesticides

No of observation: 81

***, ** and * significant at 1%, 5% and 10% probability level, respectively.