Impacts of Climate Variability and Change on Maize *(Zea mays)* production in Makhuduthamaga Local Municipality, Limpopo Province, South Africa.

By

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A dissertation submitted in fulfilment of the requirements for the degree of Masters of Environmental Science in the Department of Geography and Geo-Information Sciences, School of Environmental Sciences, University of Venda

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DECLARATION

I **Selelo Wilson Matimolane** hereby declare that the study titled **"Impacts of Climate Variability and Change on Maize *(Zea mays)* Production in Makhuduthamaga Local Municipality, Limpopo Province, South Africa"** is my own work and that all the sources used or quoted have been indicated and duly acknowledged by means of complete references. It is submitted for the degree of Masters in Environmental Sciences at the University of Venda. The work has not been submitted before for any degree or examination at any other university.

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SIGNATURE DATE

Selelo Wilson Matimolane

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DEDICATION

This study is dedicated to my parents;

My mother,

MAPELA MASIPA

For instilling in us the ability to appreciate the value of education and the freedom that lifelong learning affords one. Your words ***"thuto ga efele ngwanaka"*** are forever entrenched in my being.

And my late father,

DAVID MOLOKO "THE BRANCH" MATIMOLANE

For your endeavours to ensure that your children enjoyed the benefits of your hard work. It is unfortunate that you could not witness this moment with us.

ROBALA KA KHUTSO TLOU.

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ABSTRACT

Climate variability and change directly affect agricultural production. This is because the agricultural sector is inherently sensitive to climatic conditions and is one of the most vulnerable sectors to risks and impact of global climate change. The aim of this study was to determine maize producer's vulnerability and assess the impact of climate variability and change on maize production in the Makhuduthamaga Local Municipality, of Limpopo Province, South Africa. Climatic and maize yields data utilized in the study are for the period 1985 - 2015). Interviews were also conducted with the producers and various officials from government and non-governmental sectors.

The results illustrate significant rainfall and temperature variations both spatially and temporally. The variations observed in the average rainfall and rain days for the period under consideration were not related to the variation in yield of maize for the same period. The regression results revealed low R^2 values, indicating a weak relationship between maize yields, rain days and rainfall. Furthermore, the results revealed a significant positive relationship between annual rainfall and temperature ($r^2<0.05$ and $P<0.05$) but not a significant relationship with maize yields.

The results of the qualitative data showed that the producers' perception of the occurrence of climate variability was high, as 65.7% of the respondents indicated that the state of climate is increasingly variable. About 61.5% of the producers implemented or adopted an adaptation strategy to cope with the perceived climate variability and change. Age, gender and access to extension services were determined as important factors that determine the adoption of adaptation strategies. The vulnerability assessment revealed that producers were highly vulnerable to changing climate; this exposes producers to the risks of crop failure, loss of income and food insecurity. The study recommended (a) intervention and adaptation strategies that target mitigation of decreased rainfall impacts (b) increased access to extension service (c) empirical research around the impacts of climate change to increase producers' level of awareness.

Keywords: Climate variability and change, maize yields, vulnerability, adaptation, impact

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LIST OF ACRONYMS

BFAP	Bureau for Food and Agricultural Policy
BUR	Biennial Update Report
CV	Coefficient of variation
CO_2	Carbon Dioxide
DWS	Department of Water and Sanitation
DAFF	Department of Agriculture and Forestry
FAO	Food and Agriculture Organization of the United Nations
SADC	Southern African Development Community
SAWS	South African Weather Services
SD	Standard deviation (SD)
SSA	Sub- Sahara Africa
SPPS	Statistical Package for Social Sciences
PRA	Participatory Rural Approach
ROS	Reactive Oxygen Species
NDP	National Development Plan
NFSD	National Framework for Sustainable Development
NSSD	National Strategy for Sustainable Development and
NOAA	National Oceanic and Atmospheric Administration
UNFCCC	United Nations Framework Convention on Climate Change
WRC	Water Research Commission

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DEFINITION OF KEY TERMS

Climate Variability – refers to variations in the mean state and other statistics (such as standard deviations and the occurrence of extremes) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or due to variations in natural or anthropogenic external variability (IPCC, 2013).

Climate Change – refers to a change in the state of the climate that can be identified (for example, by using statistical tests), by changes in the mean and/or the variability of its properties, that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Climate variability, on the other hand, refers to short-term changes in climate that take place over months, seasons and years (IPCC, 2013).

Vulnerability – refers to the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change (Füssel and Klein, 2006). The term 'vulnerability' may therefore refer to the vulnerable system itself, e.g., low-lying islands or coastal cities; the impact to this system, e.g., flooding of coastal cities and agricultural lands or forced migration; or the mechanism causing these impacts, e.g., disintegration of the West Antarctic ice sheet (IPCC, 2007).

Impact – refers to the effects on natural and human systems of extreme weather and climate events and of climate change (IPCC, 2014)

Adaptation – refers to the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001a).

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Chapter 1 INTRODUCTION

1.1. Background

South Africa's agricultural economy is known for its dualism. The economy consists of a well-developed commercial farming system and a more subsistence-based production in the rural areas (SA Yearbook, 2015). The agricultural sector is significant to the economy as an employer and source of foreign income. Further, maize (*Zea Mays*) is utilised in other industries as a raw material for manufactured products such as paper, paint, textiles, and food (Macaskill, 2017).

Maize is a major crop in Sub-Saharan Africa; it is a staple for most people in the region (Moeletsi *et al*., 2016). South Africa is amongst the ten highest maize producing countries in the world, with an average of 12 million tonnes per year, contributing approximately 2% of the world's maize production (FAO, 2015). Furthermore, South Africa is the main maize producer in the Southern African Development Community (SADC) region. More than 9 000 commercial maize producers are responsible for the major part of the South African crop, while the rest is produced by thousands of small-scale producers (SA Yearbook, 2015). The largest area of farmland is planted with maize, followed by wheat and, to a lesser extent, sugarcane and sunflowers (SA Yearbook, 2015). Maize is the largest locally produced field crop, and the most important source of carbohydrates in the southern African region.

The grain industry is one of the largest in South Africa, accounting for between 25% and 33% of the country's total gross agricultural production. According to the Department of Agriculture, Forestry and Fisheries (DAFF, 2016), agricultural production is the main source of livelihood for rural communities. Primary agricultural production in South Africa contributes an estimated R263, 2 billion in 2016 and R72, 2 billion in 2015 to South Africa's gross domestic product (DAFF, 2016). Agricultural production is thus an important sector for the growth for rest of the economy.

The maize crop is produced under diverse environments (du Plessis, 2003). However, it responds positively to warm temperatures and a sufficient supply of water (du Plessis, 2003). The Free State, Mpumalanga and North West provinces are the largest producers of maize in South Africa; accounting for approximately 83% of total production. Up to 12% of

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South Africa's land can be used for crop production, with only 22% of this being high-potential arable land (SA yearbook, 2015). Rainfall is distributed erratically across the country; other areas experience regular extreme weather conditions. Almost 50% of South Africa's water is used for agriculture, with about 1.6-million hectares under irrigation (Irrigation Strategy for South Africa 2015). In South Africa, the production of maize takes place mostly on dry land with less than 10% of production being under irrigation (Baloyi, *et al.,* 2012).

South Africa is divided into 36 grain production regions. Regions 1 to 9 are winter rainfall areas (Western Cape), the Eastern Cape and Karoo, where no commercial maize is produced. Region 10 is Griqualand West and region 11 is Vaalharts in the North West. Regions 12 to 20 are all in the North West Province. Regions 21 to 28, which are in the Free State and North West, contribute approximately 62% to the total maize production in South Africa. Regions 29 to 33 are within Mpumalanga, which is the second largest maize producing province. Region 34 falls within Gauteng, region 35 is within Limpopo Province and region 36 is within Kwazulu-Natal (DAFF, 2012).

DAFF (2017) indicated that from 2010, Limpopo Province received near-normal to above-normal rainfall, while temperatures were above normal. High temperatures and insufficient rainfall during the critical stages of growth adversely affected crops in the province. Agricultural economy is a vital source of livelihood for most rural communities (Musetha, 2016). With extreme weather events such as drought, it will be difficult for producers to cope. In tropical and temperate regions, climate change without adaptation is projected to adversely impact production of grain crops, such as wheat, rice and maize, at local temperature increases of 2°C or more above the late 20th-century levels (IPCC, 2007).

The rural communities of Limpopo Province depend on growing maize and vegetables for their livelihood (Mpandeli *et al.,* 2005). Conversely, erratic and extreme climatic conditions are expected to impact the quantity yields achieved (Mpandeli *et al.,* 2005). According to Tshiala *et al*. (2011), the changing climatic conditions severely burden rural communities in Limpopo Province. Rain-fed crop production is likely vulnerable to drought conditions as a result of variability in rainfall (Masupha, 2017).

Producers' vulnerability in developing countries is increasing. This can be attributed to low level of technological advancement, lack of resources to mitigate the negative consequences of climate variability and change in agricultural production (Nath and Behera, 2011). The

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increasing vulnerability might be due to their greater dependence on agriculture for the livelihood of large populations (Nath and Behera, 2011).

Understanding the influence of climate variability and change on agricultural production is essential in order to cope with expected changes in temperatures and precipitation patterns. Due to agricultural production being climate-dependent, the agriculture sector is susceptible to changes in climatic conditions. Thus, the agricultural sector is vulnerable to the impacts of climate change (Parry and Duinker, 1990).

A distinction needs to be made between climate variability and climate change, as these concepts can be conflated. According to the Intergovernmental Panel on Climate Change (IPCC, 2013) climate change refers to a change in the state of the climate that can be identified, using statistical tests, by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate variability, on the other hand, refers to variations in the mean state and other statistics (such as standard deviations and statistics of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. Climate variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, 2007).

Climate change and intrinsic climate variability are by no means new phenomena. According to Kgakatsi (2006) discoveries by Paleo-climatologists have revealed how the climate has become more variable in the last few million years. Furthermore, according to the South African National Biodiversity Institute (2013); projections of climate change impacts under unconstrained emission scenarios are mostly negative for agricultural activities. These impacts are projected for key cereal crop production; a stable food commodity among the rural South Africa and a high value export agricultural product for the country.

Although temperature changes to date have shown a slight increasing trend, projections at the current rates of change would certainly result in dramatic effects on agriculture, the environment, economics and people (IPCC, 2013 and Kgakatsi *et al.*, 2006). While climate variability and change are not new, they have in recent years enjoyed significant attention. As observed in studies by Chi-Chung *et al.* (2004) and Osborne and Wheeler (2013), a

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substantial body of research has been undertaken on the impact of climate on agricultural production.

Several reports by IPCC (2001, 2007, and 2013) have identified Africa as the most vulnerable continent to the impacts of climate variability and change. Most of Africa's agricultural production is dependent on rain and is thus viewed as the most vulnerable sector to climate variability. The According to the United Nations Framework Convention on Climate Change (UNFCC) (2008), Africa will be the most affected by climate change. Due to changing climate conditions (i.e. increasing temperatures and drier climate); decreases of up to over 50% in yields are projected by the year 2020.

The contribution and importance of agricultural production to the economies of various countries differ. Countries with a large portion of the economy in agriculture face a larger exposure to the impacts of climate change than countries with a lower share of agricultural contribution to their economy (IPCC, 2001 and 2014; Mitchell and Tanner, 2006). Southern African economies are mostly sensitive to the direct impacts of climate change due to their dependence (heavily) on agriculture. This is because of their high poverty levels and geographic exposure (Moeletsi and Walker, 2012 and Stern, 2007).

According to scenarios on climate change, southern Africa is likely to experience increasing temperatures, frequency of extreme climate events and decreases in rainfall (Mpandeli *et al.*, 2005, Nhemachena, 2008). In addition, runoff into main river systems could be reduced; veld cover and composition could deteriorate significantly; and the frequency of wild fires could increase (Mpandeli *et al.*, 2005). The increasing temperatures, frequency of the recurrences of extreme climatic events, pose a threat to the country's natural resources and socio-economic development (COP17, 2011).

The effects of climate change on agriculture are expected to be severe in South Africa with carry-over effects on the rest of southern Africa. This is in view of shared catchments and hydrological systems and hence on river flows and the export of agricultural products (Development Bank of Southern Africa, 2009 and Kgakatsi *et al.*, 2006).

According to IPCC (2013) increases in average global temperatures are expected to be within the range of 0.3 to 4.8^{o}C by 2100. Furthermore, it is expected that tropical and temperate regions will receive unequal amount of rainfall, while the subtropical regions will receive less. However, the precise effects and how different localities will be impacted by

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climate are unclear. Projections indicate stronger impacts near the equator and in Sub-Sahara Africa (IPCC, 2007).

1.2. Problem Statement

Maize is the most important grain crop in South Africa (Moeletsi *et al*., 2016). This is because; it is both a major livestock feed grain and the staple food for majority of the South African population (DAFF, 2013). Approximately 60% of the maize produced in South Africa has been white while the other 40% is yellow maize (DAFF, 2015). The Bureau for Food and Agricultural Policy (BFAP, 2016) expects this trend to have changed by 2021, with farmers shifting towards yellow maize and oilseeds. This is because yellow maize is easier to trade globally (BFAP, 2016). White maize is generally for human consumption, while yellow maize is mostly used in animal feed production. The local consumption requirements for maize are usually around 7 million tons per year (Macaskill, 2017).

Production yields are expected to be affected by climatic variations and carbon fertilization. With doubled carbon dioxide (CO_2) offsetting much of the reduced profitability, associated with a 2°C temperature rise or a 10% reduction in rainfall, particularly in marginal areas of maize production (Walker & Schulze, 2006). This expected change in climatic conditions will affect crop production world-wide (FAO, 2007). In Limpopo Province, maize is grown almost exclusively under rain-fed conditions. A study by Blignaut *et al.* (2009) indicates that a 1% rainfall decline can lead to a 1.1% decline in maize yields during the summer season.

Several reports on the probable effects of climate variability and change on rain-fed agricultural systems in southern Africa, particularly on maize have been conducted. However, how variations in climate impact crop yield, and how they vary over time, has received less attention (Osborne and Wheeler, 2013). According to IPCC (2014), under the climate change scenarios that predict a hotter drier climate, food production, access, use and market pricing stability are expected to be affected by changing climatic conditions.

Farmers continue to face numerous risks associated with agricultural production. Climate change is expected to disproportionately affect smallholder farmers and make their livelihoods even more precarious (Harvey *et al.,* 2014). This is because farmers are frequently exposed to pests and disease outbreaks and extreme weather events which cause significant crop and income losses.

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The impacts of changing climatic conditions and increased variability on producers' productivity and livelihoods are less clear. This is because farmers are actively involved in adopting adaptation strategies to respond to climate change impacts at the farm level, based on objective determinants of adaptive capacity such as financial responses, agricultural changes, information and resources (Harmer and Rahman, 2014). A variety of studies have demonstrated that rural based small-scale producers in parts of Africa perceive and respond differently to the challenge of adverse effects of climatic variability and change (Gukurume, 2013; Maponya and Mpandeli, 2012; Shewmake, 2008).

According to Moeletsi *et al.* (2013), the climate of Limpopo Province is often characterized by unavoidable changes in extreme weather events. Intensive examination on how varying climatic change scenarios affect crop yields promises to produce insights that can be exploited, to minimize the adverse effects of climate variability (Tsubo and Walker, 2007). However, producers continue to develop strategies to shield themselves against impacts induced by annual variation in rainfall patterns (Cooper *et al.*, 2008). This study seeks to establish the impact and magnitude of climate variability and change on maize production in the Makhuduthamaga Local Municipality, Sekhukhune District, South Africa.

1.3. Justification and Rationale for the study

Limpopo Province is marked by and is particularly vulnerable to erratic and uneven distribution in rainfall, contributing to the uncertainties faced by producers through water availability (Mpandeli *et al.,* 2015). Maize is one of the main grain crops in Limpopo Province and is produced in different environmental and climatic conditions. Thus, changes in climatic conditions could positively or negatively affect production (Blignaut, *et al.*, 2009).

Effective maize production is contingent on the accurate use of inputs that can improve soil fertility and generally agricultural production (du Plessis, 2003). Maize production in South African usually exhibits variations in yield, closely related to fluctuations in seasonal rainfall (Goldblatt, 2010, Blignaut, *et al.*, 2009). According to Goldblatt (2010) the average maize production continues to be constant. Accordingly, this is a concern because local consumption of maize has increased in line with a growing population. This will affect both local and regional supply. It is therefore, important to study and understand the state of producers' vulnerability to changes in precipitation patterns.

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The Bureau for Food and Agricultural Policy (2015) projects that domestic human consumption of white maize will remain relatively constant over the long-term and any significant growth in white maize production will have to be absorbed by the export market, or alternatively, substitute yellow maize in the feed market at a discounted price. The BFAP (2015) reports that the South Africa's maize production reached 11.8 million tons during 2013/14 and consisted of 5.6 million tons of white maize and 6.2 million tons of yellow maize. The subsequent 2014/15 season yielded a crop of 14.2 million tons, the largest crop in 33 years. South Africa utilises maize predominantly for manufacturing animal feeds (39.8%) and food (37.4%) products. Exports account for 17.9% of consumption, with the remaining 4.8% being used in the production of starch and glucose (BFAP, 2015).

The Food and Agriculture Organization of the United Nations (FAO) (2015) reported that the total number of hungry people in the world has dropped to 795 million. This is 216 million people fewer than in 1990-92. As early as 2001, Watson estimated that the production of food must double in the next 35 years to meet future needs. FAO (2015) estimated that agricultural production must rise by about 60% by 2050, to feed a larger population. The World Bank (2015) projects that unless the world acts to fight climate change, 100 million more people could be driven into poverty by the year 2030. As climate change occurs, food and agriculture need to follow suit. Erratic weather patterns and the prevalence of pests and diseases resulting from climate change threaten agricultural productivity; therefore, undermine global food security (FAO, 2015).

These concerns pose serious challenges for food security and poverty alleviation. This study is aimed at determining maize producer's vulnerability to climate variability and change in the current context of expected change in climatic conditions. It is anticipated that this study will assist both maize producers and the government in the development and implementation of policies, action plans, adoption of adaptation measure and strategies in the effort to overcome the impact on climate variability and change.

1.4. Aim of the study

The aim of this study was to determine maize producers' vulnerability and assess the impacts of climate variability and change on maize production in the Makhuduthamaga Local Municipality, Limpopo Province, South Africa.

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1.5. Objectives of the study

The specific research objectives of this study are to:

- Establish the impact and magnitude of climate variability and change on maize production in the Makhuduthamaga Local Municipality;
- Evaluate maize producers' vulnerability to climate variability and change; and
- Identify adaptation measures adopted by producers', government and non-governmental agencies in response to climate variability and change

1.6. Research Questions

This research attempts to answer the following questions:

- Has climate variability and change affected maize production in the Makhuduthamaga Local Municipality?
- What adaptation measures have producers adopted to cope with the impacts of climate variability and change?
- How vulnerable are maize producers to climate variability and change?

1.7. Description of the Study Area

1.7.1. Location

The study was conducted in the Greater-Sekhukhune District Municipality, Limpopo Province, as shown in Figure 1-1. The municipality was formed in 2000, after the transition from a local council (Ngwaritsi-Makhuduthamaga), to a local municipality. Administratively, the Greater-Sekhukhune District Municipality comprises of five local municipalities. These are: Elias Motsoaledi, Ephraim Mogale, Fetakgomo, Makhuduthamaga and Tubatse.

The municipality covers a total area of 13 528 km² and is located in Limpopo Province. It is the northernmost part of South Africa and the district lies in the south-eastern part of the province. It has a total population of about 1 076 840 (The local Government Handbook, 2016). The area is known for its rampant poverty, limited employment opportunities, poor social amenities, such as water infrastructure and access roads, which are required to render services to the rural communities (IDP, *2016/17-2020/21*).

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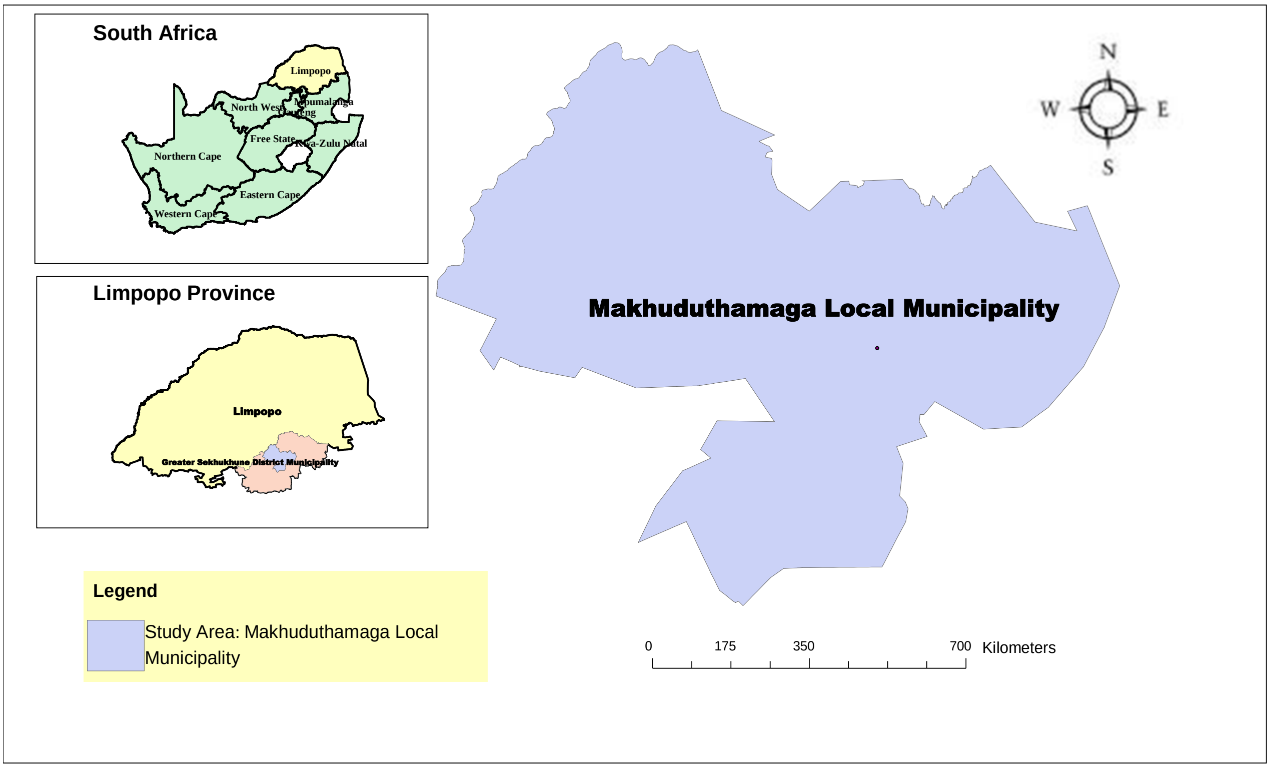

Figure 1-1 Makhuduthamaga Local Municipality

1.7.2. Climate and Agriculture

The study area is located is in an area characterised as marginal for cultivated agriculture. Certain areas are considered highly suitable with adequate supply of water for irrigation. Up to 34% of the area (1,370 ha) is suitable only to natural or planted pastures. The remaining area (2,642 ha) is potentially suitable to horticulture as well as grain and oil seed production (Petja *et al.*, 2014).

Makhuduthamaga Local Municipality is susceptible to major climate conditions, which can oscillate between floods and droughts. The Municipality is located in a summer-rainfall region. It receives more than 80% of its total rainfall between September and March, at times extending to April. The average annual rainfall ranges from 500–800 mm, with the mean average annual temperature of 20°C. The area has a mean average growing season of about 167 days, considerate of 27.5% of rainfall coefficient variance. Thunderstorms with the associated low soil penetration and high level of erosion are common in the area. The high evaporation risk results in low moisture supply capacity. Irrigation is therefore essential for cultivated farming practices (EnviroGIS, 2009).

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1.7.3. Profile of the study area

Table 1-1 Profile of the study area

Characteristic	Description
Population.	The Makhuduthamaga Local Municipality has a total population of 274 358 people, or 65 217 households. It is the second leading municipality in the Sekhukhune District in terms of population figures, with 25% of the District population living in the Makhuduthamaga Local Municipality.
Climate	The climate varies between floods and drought with annual rainfall between 500 - 800 mm.
Gender distribution	56.6% females and 43.3% males.
Water access	62% of the household receive water below the RDP level
Road access	Degraded road infrastructure due to heavy rains
Distance to town	Closest towns are Jane-Furse and Lebowakgomo but people prefer Polokwane which is about 150 km away and is more developed.
Education	Levels of education in the Makhuduthamaga Local Municipality community are low, with 23,4% of persons 20 years and older having had no schooling; 20.6% having completed some level of high school, and 5.5% or 72 completing high school (matric). The schooling situation has improved since 2001, when 44.3% of people older than 20 never attended school.
Electricity	Electricity backlogs of 36% households.
Sanitation	The municipality is facing sanitation backlogs of 38,034 households.
Agriculture	The communities depend on rainwater for agriculture. The Setlabotswana, Crokodile and Platkip irrigation schemes are the only commercial irrigation schemes equipped with floppy irrigation systems. The primary agricultural nodes are in ward 12, 17, 22, 02 and 05. Agricultural activities employ 6% of the population (Census, 2011) and almost 80% of the farms are under land claims. The most common crops planted are wheat, maize, sunflower, sorghum and vegetables. Some of the community members have back yard gardens but also communal gardens are preferred in the area. These projects absorb about 19% of the workforce in the area.
Mining	Mining is minimal and provides 1% employment in the area.

(Adapted from IDP, 2016/17-2020/21)

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1.8. Outline of the dissertation

The dissertation comprises of five chapters. Chapter 1 presents the background, problem statement, justification and rationale for the study and the description of the study area. Chapter 2 introduces the impacts of climate change on agriculture, maize production in South Africa and the climatic conditions of Limpopo Province maize industry, showing the importance of maize production to the rural communities in Limpopo Province. The South African climate change policy landscape is also reviewed. Examples of how maize productivity is expected to be affected by the expected change in climate in different parts of the world are given. Chapter 3 presents the adopted research methods, and Chapter 4 presents the results and discussion. Chapter 5 presents the study conclusions, summary of the findings and recommendations that may be adopted to ensure that producers' can cope with climate variability as well as the change challenges. The limitations of the study are also presented. This chapter concludes with recommendations on areas of further research.

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Chapter 2 LITERATURE REVIEW

2.1. Introduction

This chapter presents a review of empirical studies conducted on the impacts of climate change on agriculture, maize production and the climatic conditions and the effects of temperature and water stress on crop growth. A review of the South African climate change policy landscape and influences is also presented. Examples of how maize productivity is expected to be affected by the change in climatic conditions in different parts of the world are also provided. This review aims to determine the extent of vulnerability of the producer's to climate variability and the challenges that producers' will encounter in the short-term and long-term due to climate variability and change.

2.2. Agricultural Production in South Africa

According to SA Yearbook (2015), the SA agricultural sector operates as a dual economic sector. Comprising of well-resourced modern commercial farming sector that contributes significantly to the gross value of agricultural production in the country (Mudhara, 2010), alongside more subsistence-based small-scale farmers, mostly poor resourced in the rural parts of the country (AgriSETA, 2010). The South African agricultural production is a highly integrated system through its agriculture production value chain (Boye and Arcand 2013).

South Africa is independent in almost all major agricultural products and is a net food exporter of produce. South Africa's primary agriculture sector contributes significantly to the country's economy – contributing an estimated R263, 2 billion in 2016 and R72, 2 billion in 2015 to South Africa's gross domestic product (DAFF, 2016). In 2013, the agriculture sector accounted for approximately 10% of formal employment (DAFF, 2016).

The farming regions vary according to climate, natural vegetation, soil type and farming practices (Agbiz, 2016). The main agricultural activities are market-oriented, highly diversified and range from intensive crop production of all the major grains (except rice), and game and cattle ranching in the bushveld and sheep farming in the arid regions (Agbiz, 2016). Maize is the most grown grain crop, followed by wheat, oats, sugar cane and sunflowers (Agbiz, 2016). South Africa is the leading and most active producer of maize in

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the southern African region and accounted for 42% of Africa's maize trade, with 69% of these being in the form of imports in 2015 (Mordor Intelligence, 2017).

In South Africa, agricultural production occurs in the context of challenging conditions, including erratic weather and extreme events, poverty and food insecurity. This is because agricultural production is dependent on rainfall. Drought poses a serious challenged for agriculture in the country due to aridity. Around 13.5% of the land is suitable for crop production, among which only 3% is considered as high fertile land (Mordor Intelligence, 2017). While the agricultural sector only contributes around 2.7% to the South African GDP (DAFF, 2016), it still plays a crucial role in employment and export income generation.

2.3. Agricultural Production in Limpopo Province

Limpopo Province is the 5th largest province of South Africa (similar in size to the Free State and Western Cape Provinces). It contributes 10.6% of the country's total land area (LEDET, 2016). Along with the Free State Province, Limpopo Province is regarded as the country's breadbasket and is one of South Africa's most important agricultural regions and a significant producer of livestock, vegetables and fruit (Dludla, 2014).

Agriculture has been identified by the Limpopo Provincial Government as one of the primacy areas for developing the province`s economy for its role in employment opportunities among the rural communities (Baloyi, 2012). As the national agricultural sector, the Limpopo Province agricultural sector is also characterized by dualism, with two different production systems (DAFF, 2012). Up to 33% of households in Limpopo Province are classified as agricultural households. Limpopo Province is also home to 16% of South Africa's agricultural households (Musetha, 2016).

Most of Limpopo Province is situated within a subtropical climate, with a varied climate (Oni *et al.,* 2012). The climate of Limpopo Province is favourable for the cultivation of produce grain crops (maize, wheat, and sorghum) and tropical fruits (such as litchis, mangoes, and oranges) as well as vegetables such as potatoes, and onions (Musetha, 2016). The challenges faced by the province are similar to those faced by the country. According to Maponya and Mpandeli (2012), drought is a serious problem in the province because the province has a semi-arid climate with low, erratic rainfall. The uneven distribution and erratic rainfall in the province pose difficulties such as food production and insecurity, loss of

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income and livestock (Tshiala and Olwolch, 2010), thus undermining the potential of the sector to contribute significantly to the provincial economy. An estimated 62% of Limpopo Province's maize area is already attributed to small farmers, and it is these rural households that would feel the economic pressure more than others (LEDET, 2016).

2.4. Maize production in South Africa

According to Mensah *et al*. (2009), maize is ranked the third most important grain crop after rice and wheat in the world. In South Africa, maize is produced throughout, with the Free State, Mpumalanga and North West Provinces being the largest producers, accounting for over four-fifths of total production. Most maize production is on dry land, with less than 10% being produced under irrigation (Baloyi, 2012). The main maize planting time is between mid-October and mid-December. However, climatic conditions of a particular season often determine the planting period as well as the length of the growing season.

Figures on maize yields vary from season to season, but generally about eight million tons of maize grain is produced annually in South Africa on 3, 1 million hectares *(*Farmer's weekly, 2015*)*. Maize accounts for the largest area of planted farmland, followed by wheat and, to a lesser extent, sugarcane and sunflowers (DAFF, 2012). SADC produces 29 million tons of maize, and nearly half (about 42%) of that is produced in South Africa. Moreover, about 70% of SADC (excluding South Africa) annual maize imports come from South Africa, implying that a decrease in South Africa's maize production could affect the entire region (Agbiz, 2016).

In 2014, South Africa exported 2, 1 million tons of maize, which translated to R6, 5 billion in export revenue (ITC, 2017). However, South Africa will not achieve comparable export revenues in the 2014/2015 production year due to unfavourable weather conditions. In 2016, South Africa, emerging from the worst drought since 1904, imported white maize from Mexico (95.1%) and the US (4.9%), and yellow maize from Argentina (88.9%) and Brazil (11.1%) (Macaskill, 2017).

2.5. Climate requirements for maize crop production

According to Moeletsi (2010) and Moeletsi *et al*. (2011), in southern Africa agricultural productivity is affected by the high variability of inter-annual and intra-seasonal rainfall which

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has negative impacts on food security, especially at the level of small-scale subsistence farmers. Adverse climatic conditions and irregular rainfall have the potential to cause famines during occasional droughts.

Climate variability and change is expected to have a significant impact on South Africa's maize production (Akpalu *et al.,* 2009). Climatic variables such as temperature, precipitation, moisture as well as frequency of heat waves and droughts influence maize production in Limpopo Province (Musetha, 2016). Maize is usually a summer crop, grown mostly in semi-arid regions of the country (Baloyi, 2012), and is highly susceptible to changes in precipitation and temperature (Durand, 2006).

Maize is a C4-plant, adapted to a warm, dry subtropical climate, with plentiful sun, occasionally abundant rainfall during the night and limited rainfall during the daytime, low wind speed, and loamy soils (Odgaard *et al.,* 2011 and Andersen, 2000). Erratic rainfall before the flowering period of a plant, and excessively high temperatures during the same stage has a great impact on the yield (Hu & Buyanovsky, 2003).

According to du Plessis (2003) due to the varied environment in which maize is produced, the crop requires an estimated 450 mm and 600 mm of water for successful harvest. It also requires a frost-free growing period which has a detrimental effect on productivity (Moeletsi and Walker, 2012). Although maize has certain levels of tolerance to adverse conditions, erratic rainfall and drought affect productivity (Akpalu *et al.,* 2009).

At maturity, it is estimated that each maize plant will have consumed about 250 litres of water (du Plessis, 2003). This allows it to survive in areas with short periods of rainfall and irregular water supplies. Early-maturing varieties mature in 90-100 days and can be planted after a late-maturing variety in zones with two seasons of rainfall. Late-maturing varieties mature in 110-120 days and are good for zones with a long rainy season (Agribiz, 2016). This allows it to survive in areas with short periods of rainfall and irregular water supplies. Early-maturing varieties mature in 90-100 days and can be planted after a late-maturing variety in zones with two seasons of rainfall. Late-maturing varieties mature in 110-120 days (Figure 2-1) and are good for zones with a long rainy season (Agribiz, 2016).

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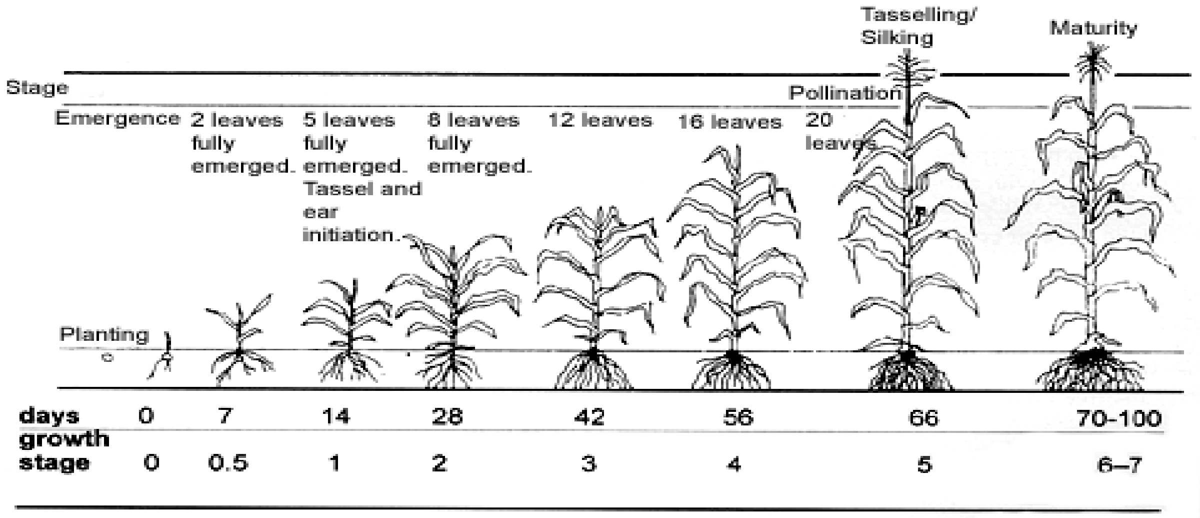

Figure 2-1 Maize plant growth stages (Source: Beckingham, 2007)

2.6. Agricultural production and climate variability and change

Climate conditions are the primary determinant of agricultural productivity and any significant change in climate in the future will influence crop and livestock productivity, input supplies and other components of managing agricultural systems: (Adams *et al*., 1998). Rainfall and temperature are some of the climatic variables that fluctuate greatly in spatial and temporal terms, having an impact on agricultural activities (Moeletsi *et al.,* 2011). These variables regulate the development stages of crops (Moeletsi, 2017). This implies that if there are any variation in climatic patterns, production of different crops would be affected. Increases in temperature and changes to rainfall pose the greatest threat to agriculture and water supplies in the region (Tadross, and Johnston, 2012).

According to the World Bank, in 2014 close to 800 million people around the world or 78% of the world's poor people lived in rural areas and relied on agriculture for their livelihood and poverty alleviation. The Koninklijk Nederlands Meteorologisch Institute (2006) observed that for many decades now, multi-decadal rainfall oscillations have occurred in Southern Africa. Models project an increase in the extreme dry events of over 30% over the Kalahari region with extreme low rainfall set to increase by up to 50% by 2100 for Southern Africa (The Koninklijk Nederlands Meteorologisch Institute, 2006).

According to the Institute for Security Studies (2010), there is a need for Africa to ensure that the current impacts of climate variability and change on economies and populations are

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recognised and that a development agenda is integrated into climate negotiations. This therefore justifies the need for nations to find adaptation measures.

2.7. Projected climatic changes for South Africa

Climate change is generally accepted as an occurring reality (Shongwe *et al*., 2009; Stocker *et al*., 2013 and Zhang *et al*., 2015) and poses a great challenge to agricultural production in many ways (IPCC, 2011). Climate change is expected to exacerbate climate variability as well as the frequency, intensity and spatial extent, of extreme weather and climatic events (IPCC, 2012). It is likely that the annual variation in rainfall will increase the severity and frequency of both drought and floods (IPCC, 2013).

Climate change projections for South Africa up to 2050 and beyond under an unmitigated global emissions scenario project the mean air temperature near the ground is to increase by 1.4°C to 5.8°C (IPCC, 2013). Temperature increases will be greater in the inland areas than at the coast. Changes in global climate have been observed as generally consistent with model projections and are likely to continue to occur for many decades to come, even if mitigation efforts are successful. This is due to lays and inertia in the global biosphere response.

Greenhouse gas emissions through human activity are predicted to increase global average temperatures by 2 - 5.4°C by 2100 (SRES A2 Emissions Scenario: IPCC, 2007). Most climate model projections suggest less rainfall in the eastern and northern parts South Africa, where degradation is currently most severe (DEA 2004). The rising temperature will lead to greater evaporation and net water decrease, which will result in drier soils, even if rainfall does not decrease (South Africa's Initial National Communication, 2011). The key sectors to be significantly impacted on by these changes are highlighted below.

2.7.1. The impact of climate change on the agricultural sector

South Africa's climatic regions range from semi-desert to Mediterranean and subtropical conditions. The country is characterised by uneven distribution of rainfall, with the country's average annual rainfall being 450 mm per year. The western part of the country exhibits dry desert-like conditions, generally with less than 100 mm of rainfall per year. The eastern part

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of the country exhibits humid subtropical conditions with about 1 000 mm of rainfall per year (DWAF, 2002).

According to Gbetibouo and Hassan (2005) the locality and season are critical factors in determining the potential impacts of climate change on crop production. Climate change in Limpopo Province is taking place in the context of other developmental stresses, as such is vulnerable to climate change impacts. This is due to its exposure to extreme weather events (Levey and Jury, 1996; Tennant and Hewitson, 2002; Cook *et al*., 2004).

Producers' vulnerabilities in the agriculture sector mainly revolve around the ability to cope with the potential impacts of climate to grow certain crops in marginally drier and hotter environments. The production of fruits is expected to be impacted significantly due to their high reliance on optimal temperature and rainfall conditions. Small-scale farmers located in marginal areas, such as Limpopo Province, will also have to attempt to farm under water-stressed conditions (DAFF, 2012).

2.7.2. Climate change and water scarcity

Climate change is also projected to impact on water resources. As a result, the intensity, quantity, timing and form of precipitation are expected to be more variable (Adams and Peck, 2008). The Council for Scientific and Industrial Research estimates that because of low average (and irregular) rainfall, exacerbated by climate change, there will be a water deficit in South Africa by 2025 (Talk Radio, 2015). According to Adams and Peck (2008), high temperatures are expected to result in high water deficits during the summer season. This will lead to decreased soil moisture and more frequent and severe agricultural drought.

Climate change and associated water scarcity are limiting factors to crop production. In regions reliant on rainfall for agricultural productivity, the availability water for the physiological development of a maize crop is critical (Moeletsi and Walker, 2012; Wetterhall *et al.,* 2014). Crop water requirements depend mainly on the nature and stage of growth of the crop, together with the environmental conditions (Moeletsi, 2010). Efficient use of water at various stages of the crop development is therefore important to improve yields and crop production (Walker and Tsubo, 2003).

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2.7.3. The development of heat waves

Heat waves, also referred to as extreme heat event (i.e. occurrences with maximum daily temperatures T_{mxd}> 30°C on 3 or more consecutive days) and extreme heat waves (occurrences with T_{mxd} ≥ 35°C on 3 or more consecutive days), is defined as a period of abnormally hot weather (IPCC, 2012). According to Schulze (2011) the median number of heat waves per annum is projected to increase by at least 30% to more than double from the present to both the intermediate and more distant futures.

Heat waves occur throughout many regions of the globe, with impacts on their various sectors. Various studies across the world have been conducted on heat waves. These have focused on the characteristics of extreme high temperature events, heat wave intensity and frequency (Easterling *et al*., 2000; Meehl and Tebaldi 2004; Lau and Nath 2012). Regionally, Lyon (2009) and New *et al*. (2006) studied the behaviour of heat waves in South Africa and trends in indices for temperature extremes over west and southern Africa, respectively, indicating the increase in occurrence, intensity and trends in daily temperature extremes

IPCC (2012) notes that models project substantial warming in temperature extremes by the end of the 21st century. Thus, it is expected that the length, frequency, and/or intensity of warm spells or heat waves will increase over most land areas. Schulze (2011) further predicted that the case of extreme heat waves, the median number is projected to more than double into the intermediate future, with the most affected areas being those that are already very hot today, the eastern and northern borders of South Africa and the Northern Cape.

In Limpopo Province, the occurrence of heatwaves is variable, with the highest frequency of occurrence in the southern part of the province and the northern part of the Limpopo valley, (Tshiala, 2014). The impact and characteristics of a heat wave vary considerably from region to region. Due to the limited access and availability of high quality climate and weather data and information in many Africa countries, it is difficult to develop a good understanding of the hazards caused by high temperatures and to carry out comprehensive risk and vulnerability assessments (Ogallo, 2010). The most commonly experienced types of heat waves are those that occur over several consecutive days (Khaliq *et al.,* 2005; Huth *et al.,* 2000 and Burt, 2004)

According to Lesk *et al.* (2016) several extreme weather disasters have partially or completely damaged regional crop production with heatwaves and drought events substantially damaging crop production across the globe. According to Deryng *et al. (*2014)

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extreme heat stress during the crop reproductive period can be critical for crop productivity. Crops are especially vulnerable to heat around anthesis (Deryng *et al.,* 2014).

2.8. Effects of Temperatures and Water Stress on Crop Yields

The impact of climate change on grain crop yields, specifically on how the crop responds to different temperature levels during different stages of active growth under controlled trials, has been conducted in several studies (e.g., Du Toit *et al.,* 2002; Kiker *et al.,* 2002; Durand 2006). In Africa and Latin America it was found that maize yields would increase and decrease in various areas (Jones and Thornton, 2003), with a projected 10% in total production for both regions by 2055 due to the expected increase in temperature and erratic rainfall suitable for maize production(Jones and Thornton, 2003). Chipanshi *et al.* (2003) also showed a reduction in maize yield by between 21.6 and 35.8% in Botswana due to increases in temperature by 2 and 3°C respectively. The study concluded that grain farming is mostly affected by high temperatures and inadequate precipitation.

Generally, high temperatures and water deficit affect plants chloroplasts and stimulate the production of reactive oxygen species (ROS) in the chloroplast. Excess ROS "is one of the reasons for low activity of chloroplast specific enzymes, with enhanced sensitivity to oxidative stress, low adenosine triphosphate levels and structural arrangements in the thailakoid membrane" (Kreslavski *et al.*, 2007: p.185). According to Kreslavski *et al.*, (2007) as photosynthesis takes place in the chloroplasts, the thailakoid membrane should be in a good condition to enable a plant to resist and adapt to stress caused by high temperature and water deficit.

Stewart *et al.* (1997) showed that during vegetative growth, maize has a maximum response to temperature of between 25°C and 30°C, and during reproductive growth, maize responds well to temperatures above 12°C. A study by Sage and Kubien (2007) showed that low temperatures affected C4 plants in different ways. In Australia, Ramadoss *et al.* (2004) found that maize crop that experienced extremely high air temperatures (41°C) over several days, compounded by water stress during anthesis, had lower grain yields compared to those that experienced lower temperatures. The change in temperature from high to low was found to stunt the growth rate of plants. Although the effect of temperature on the photosynthesis seems to affect grain yield, temperature can also affect the crop at different stages of its growth.

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In Zimbabwe, extreme weather events and the frequency and intensity of droughts are increasing, as well as the conditions likely to reduce harvests and affect the suitability of crops (Cairns *et al.,* 2013). According to Makuvaro (2014), in Zimbabwe the impact of rainfall on agricultural production is greater than temperature. The rainfall received is impacted by the high mean summer temperatures experienced and thus is often rendered less effective for maize production due to high evaporation. The expected effects of climate change, with greater variability among regions and localities, remain uncertain and require further investigation (Cairns *et al.,* 2013).

2.9. The impact of climate change on crop production: Uncertainties

An understanding of the impacts of climate change on crop productions, considering uncertainties, is essential for properly identifying and decision-making agricultural practices that are sustainable. The effect of climate change on crop productivity can be predicted by evaluating the outputs from crop simulation models when run with control climate and climate change scenarios from climate models (Easterling *et al.,* 2007). However; projections and quantification of the impact of climate change on crop yields are subject to uncertainties, and such are essential for the effective use of the projection models, to inform the decisions for adaptation and mitigation (Zhang *et al.,* 2015a).

According to Olesen *et al.* (2007) uncertainties and sources of variation in projected impacts of climate change on agriculture and terrestrial ecosystems depend not only on the emission scenarios and climate models used for projecting future climates, but also on the impact models used, and the local soil and climatic conditions of the managed or unmanaged ecosystems under study.

2.10. The impact of non-climatic factors on maize production

According to a study by Ngoma (2008), non- climatic factors that influence maize production range from infrastructure, credit, markets and high yielding seeds. From the same study, it was argued that a reduction in maize production was attributed to lack of credit facilities to farmers. Furthermore, for those that were able to access credit facilities, the inputs were delivered late. Farmers' choice of agricultural management practices is dependent on farmers' interests, goals and available resources. Several studies (Gasson, 1973; Granovetter, 1985; Hogan *et al.,* 2011) argue that farmers' management practices are based on a complex set of economic and noneconomic goals which are relevant to them at a given

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time and location. Farm level agricultural management practices involving prolonged and intensive tillage and use of fertilization to improve crop yields have resulted in the degradation of soil qualities through the increased rate of erosion and nutrient leaching (Sainju *et al,.* 2003). These practices influence crop production and agricultural performance at farm level. Subsequently, agricultural management practices that sustain crop yields and improve soil and environmental qualities are required.

2.11. South African climate change policy landscape and influences

The South African government has acknowledged that climate change is a reality and its potential impact on various sectors contribute on the economy, food security, livelihoods and agriculture; especially on rural base small-scale farmers. The importance of agriculture to the South African economy requires comprehensive and all-encompassing policies to address these challenges. The South African water infrastructure and management capacity support adapting and responding to the variable climate; climate change is expected to exacerbate this variability with significant hydrological, ecological, social and economic consequences (DWA, 2013). Several of these policies, strategies and measures initiated by the government to combat climate change are highlighted below:

2.11.1. National Department of Agriculture Forestry and Fisheries Strategic plan

The National Department of Agriculture, Forestry and Fisheries Strategic Plan for South African agricultural sector has outlined sustainable resource management as one of the three core strategies where issues of adaptation to climate change and sustainable development are to be dealt with.

2.11.2. National Climate Change Response Policy (2011)

The policy outlined two important objectives: effectively managing inevitable climate change impacts through building resilience and response capacity; and making a fair contribution to the global effort to stabilise greenhouse gas concentrations. The National Climate Change Response Policy is used as a guide to develop a comprehensive suite of climate change adaptation measures which includes desired emissions, reduction outcomes, promoting innovation and investment in renewable energy, encouraging energy efficiency, and creating

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a national system for greenhouse gas data collection. The policy outlines a risk-based process approach to adaptation, identifying short and medium-term processes. Interventions to be taken are outlined and the areas of concern, such as water, agriculture, forestry, biodiversity and human settlements, are identified. Resilience to climate variability would form the basis of disaster management in future.

2.11.3. The National Environmental Management: Air Quality Act. 39 (2004)

The National Environmental Management: Air Quality Act No. 39 of 2004 (amended) seeks to reform the law regulating air quality in order to protect the environment. This is achieved by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development, while promoting justifiable economic and social development. This is done to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government, for specific air quality measures, and for matters incidental thereto.

2.11.4. National Development Plan (2012)

Climate change is one of five critical trends noted in the National Development Plan (NDP), which recognizes that “South Africa is not only a contributor to greenhouse gas emissions – it is also particularly vulnerable to the effects of climate change on health, livelihoods, water and food, with a disproportionate impact on the poor, especially women and children. While adapting to these changes, industries and households must reduce their negative impact on the environment. This will require far-reaching changes to the way people live and work” (NDP, 2012). The NDP recognizes that the impacts of climate change will be felt substantially in the water arena, and reflect the need to build economic sustainability and resilience to “enhance the resilience of people and the economy to climate change”.

2.11.5. National Water Resource Strategy (2013)

The Department of Water and Sanitation (DWS) has published an updated National Water Resource Strategy (2013) following the initial release of the March 2004 edition by the Department of Water Affairs and Forestry. This strategy also includes an analysis, managing of water resources and research of the impacts of climate change on South Africa’s water resources. Research and innovation conducted by the Water Research Commission (WRC) and other research bodies such the Council for Scientific and Industrial Research and Agricultural Research Council in areas such as wastewater treatment, water quality and

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water ecosystems, skills and capacity within the sector, climate change and water conservation and water demand management approaches, have influenced the themes and interventions contained in this Strategy.

WRC is expected to continue its current research into the potential impacts of climate change on water. The research will include water quality issues as well as research into the social elements of adapting to climate change. Further research is expected to increase the accuracy of possible future climate change predictions by improving their scientific basis and initiating additional research into climate and water models, to develop more robust and dependable results. Within the department, research on water and the adverse impacts climate variability and change may have on water resources, are also investigated.

2.11.6. The National Environmental Management Act 107 (1998)

The National Environmental Management Act no 107 of 1998 was amended to consider changes, which have been made in legislation, with respect to pollution and waste management, environmental impact assessments and other general environmental issues. In this Act, the contribution of air pollution (resulting in high CO_2 emissions) and waste disposal (resulting in methane emissions) have been recognised as high contributors to the greenhouse gases.

2.11.7. The Disaster Management Act 57 (2002)

The Disaster Management Act no 57 of 2002 establishes a framework for preparedness for disasters in South Africa and the region, caused by extreme climatic events such as floods, droughts, and heatwaves. This Act gives guidance on how adaptive capacity to disasters of vulnerable communities, and not just response strategies, should be undertaken.

2.11.8. National Strategy for Sustainable Development and Action Plan (2011–2014)

Department of Environmental Affairs has developed a National Strategy for Sustainable Development and Action Plan (NSSD 1) 2011–2014, a successor to the South Africa National Framework for Sustainable Development (NFSD) approved in 2008. Responding effectively to climate change is one of the five strategic objectives identified in the NSSD 1. The NSSD 1 builds on the 2008 NFSD and several initiatives that were launched by the business sector, government, NGOs, civil society, academia and other key role players to address issues of sustainability in South Africa. The NSSD 1 was to be implemented during

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the period 2011– 2014. The lessons and evaluation of progress regarding the implementation of NSSD 1 will inform NSSD 2 (2015–2020).

2.11.9. United Nations Framework Convention on Climate Change Reports

As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) (The government of the Republic of South Africa signed the convention in June 1993), South Africa submitted the First National Communication report in December 2003 and the second national communication report in November 2011, in which several substantive advances in the national understanding of climate-change-related issues were reported. The Department of Environmental Affairs compiled a report in response to South Africa's obligation to provide a Biennial Update Report (BUR) to the UNFCCC, which follows on from the 2011 Second National Communication in November 2014. BUR comprised of seven chapters, with each chapter highlighting a specific aspect of South Africa's response to climate change; (a) National circumstances (b) National greenhouse gases inventory (c) Mitigation actions and their effects (d) Financial resources, technology transfer (e) capacity building and technical support received (f) Support received for the preparation of the BUR (g) Measurement, reporting and verification in South Africa

2.11.10.Working for water programme

The DWS working for water programme aims to sustainably control invading alien species through the process of economic empowerment and transformation. In doing so, the programme is highlighting the importance of adaptation to climate change by controlling alien species whilst preserving water and optimising the use of natural resources.

2.12. Responses to Climate Change

Understanding the potential impacts to both natural and man-made systems is critical to the success of implemented response measures. Response to climate variability and change can be addressed through employing various strategies, such as those outlined below and, specifically, through the implementation of various policy approaches.

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2.12.1. National Level Adaptations

Agriculture is generally one of the sectors exposed to impacts of government policy changes, influencing access to markets, input costs, product pricing and exports. Accordingly, any change in policies has the potential to greatly affect the sector (Parry and Duinker, 1990). The changes in government policy driven by expected climate change would substantially influence how the sector ultimately responds and copes with climate change. Government policies relating to land and water resources, as the most important elements affecting agriculture as there are the limiting resources for crop growth in Southern Africa (Moeletsi, 2010), should be more explicit in having the implementing agencies give due consideration to the possible impacts of climate variability and change.

Given the uncertainties on the magnitude of impacts and how different localities will be affected, the ability of government to directly promote adaptation to projected change is limited. Policies to address the anticipated impacts should thus allow for flexibility and revision when new research on the success and failures, the magnitude and direction of climate variability and change, become available. Using different policies, governments should strike a balance between both reactive and anticipatory adaptive measures. Ideally, a policy- relevant research program could help identify appropriate actions as the current state of knowledge evolves.

2.12.2. Farm Level Adaptations

Internationally, agricultural adaptation at the farm level is very high (Smith *et al.*, 2012). Farm level adaptations arise from frequent access to extension services and farmers' perception of changing conditions (Juana *et al.,* 2013, Shongwe, 2009). According to Smith *et al.* (2012), farmers operate in varied environments with climatic conditions also varied from season to season. Therefore producers should carefully re-examine the appropriateness of their land use and management practices and farm infrastructure. This would allow producers to decrease their vulnerability to climate variability and change.

Diversifying agroecosystems can greatly strengthen the biophysical and socio-economic resilience of farmers and rural communities, to assist both the biophysical and socio-economic resilience of farming systems (Altieri *et al.,* 2015). According to Zhang *et al.,* (2007) farmers must manage this diversified farming system, to generate critical ecosystem services to agriculture. The advantages of diversification include improving food-security,

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household income and minimizing threats of total crop failure (Nyasimi *et al.,* 2017 and Ncube, 2012).

Given that climate change could worsen the challenges of waters scarcity through reduced rainfall and higher evaporation regime (Mpandeli *et al*., 2005); technologies such as micro-irrigation, that allow the economical use of water, should be given priority. Southern Africa experiences a very high climate variability, which has negative impacts on food security, especially at the level of small-scale subsistence farmers (Moeletsi, 2010). While South Africa is recognised as a water scarce country (Power 987, 2018 and Development Bank of Southern Africa, 2009), the situation is likely to worsen in the future.

2.13. Adaptive Capacity

The IPCC (2007) defines adaptive capacity as the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies. Climate change adaptation is a factor of the capacity to plan, design and to implement options or measures, while understanding the determinants of and limitations to adaptive capacity, has become crucial for effective responses (Smith *et al.,* 2010).

According to Dow *et al.* (2013), some adaptation limits have been clearly identified, primarily for ecological systems. However, little is known about limits in social systems — whether there are social limits to adaptation, what influences their likelihood and what the consequences of reaching such limits might be. Adaptation limits in a system has broad implications, a limited ability to adapt is a key rationale for considerations of adaptation costs and benefits, and of equity concerns. However, research suggests that opportunities and resources to adapt may benefit for many social actors, whether these are individual households, businesses

According to Brooks *et al.* (2005), the design and implementation of effective adaptation strategies to reduce the probability and the magnitude of climate change impacts is dependent on adaptive capacity. Adaptive capacity is most easily understood in terms of the capacity of a particular system to adapt and cope better with climate change, including variability (Brooks *et al.,* 2005). Considerable attention has been devoted to the characteristics of systems that influence their propensity to adapt as part of impact and vulnerability assessment) and/or their priority for adaptation measures. These characteristics

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have been called determinants of adaptation (IPCC, 2001). Several of these determinants are discussed below.

2.13.1. Economic Resources

The economic condition of communities is a determinant of adaptive capacity (Burton *et al.*, 1998; Kates, 2000). The ability of communities to adapt is higher and directly related to increase in economic resources and lower, with reduced economic resources (Bhadwal, 2006). Neighbourhoods with higher levels of household income are better able to adapt through the transfer of flood impacts from health to economic investment and loss. As an example, it is recognized that prosperous nations have a greater capacity to adapt because they have the economic resources to invest in adaptive measures and to bear the costs of adaptation to climate change impacts and risks as compared to poorer nations (Burton, 1996).

2.13.2. Technology

Access to technology plays a critical role in adapting to climate change within sectors, such as agriculture (IPCC, 2007). Often, technological adaptations and innovations, such as those involving technology (e.g., warning systems, crop breeding and irrigation, flood control measures), are developed through research programmes undertaken by governments and the private sector (Smit and Skinner, 2002). Although building technological capacity can be considered a key aspect of adaptive capacity, many technological responses to climate change are closely associated with a specific type of impact, such as extreme events. Lack of access to technology therefore has the potential to seriously hinder a nation's ability to adopt and implement adaptation options; therefore; adaptive capacity is likely to vary, depending on access and adoption of technology across levels and generally in all sectors (Burton, 1996). It is accepted that the ability of regions/nations to continuously develop, adopt and reinvent old technologies is an important determinant of adaptive capacity.

2.13.3. Information and Skills

Countries with more economic resources or research capacity have greater adaptive capacity than developing nations and those in transition (IPCC, 2001). Downing *et al.* (1996) noted that an understanding and availability of weather hazards information on climate variability and change are factors in the implementation of adaptation measures. Thus generally adaptive capacity is expected to be low without informed, skilled and trained

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personnel. Timely access to information increases chances of timely and appropriate adaptation.

2.13.4. Adaptive Capacity Constraints

States and governmental agencies are important role players and determinants in building adaptive capacity. As research on adaptive capacity evolves, its assessments inclined on the premise that on managed systems, such as agriculture, are likely to adapt easily, given sufficient resources, as compared to less-managed ecosystems (Strzepek and Smith, 1995; Burton, 1996; Toman and Bierbaum, 1996). Research into factors that influence negatively or positively to a systems adaptive capacity is fairly lacking (Engle and Lemos, 2010). The equality of decision making and knowledge availability has critical effects for decision makers tasked to build adaptive capacity through governance structures and institutional means.

Several studies (Adger *et al.,* 2005; Berkhout *et al*., 2006; Eriksen and Kelly, 2007) have illustrated that adaptive capacity is influenced by other factors such as human capital and governance structures. Results from research on vulnerability and adaptive capacity have shown that some dimensions of adaptive capacity are standard, while others are specific to particular climate change impacts. Standard indicators include factors such as education, income and health, Indicators specific to a particular impact, such as drought or floods, may relate to institutions, knowledge and technology (Tol and Yohe, 2007).

At a local level, communities are often more likely to cope with change if they have requisite information, skills and knowledge about potential future threats, as well as an understanding of how to adapt to them (Jones *et al*., 2010). Fankhauser and Tol (1997) noted that adoption of adequate adaptation strategies necessitates an understanding of likely future change and its complexity, knowledge about adaptation options, the ability to assess options, and the capacity to implement suitable interventions. Knowledge, information and skills are therefore important determinants of adaptive capacity – with obvious links with the institutional context and the governance of knowledge. Access to knowledge and information is a catalyst in ensuring local consent and awareness of the needs of particular groups within a community (Ospina and Heeks, 2010).

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2.14. Research Support and Development

Government and institutional support for research and development can assist producers on how to deal with the impacts of climate change. Directed policy development for the non-governmental and private sector can also be of major contributor. Economic resources and available facilities can to influence short-term adaptation such as the pace at which crop varieties, agricultural technologies, and management systems are developed and implemented for adaptive capacity against climate change (Smith *et al.*, 2012). “There is a need to bridge the institutional separation of research and extension services, as this has tended to minimize the responsibility for developing technology that is farmer based and problem oriented.

It is also important that government fully utilize information from research and development bodies in its formulation and/or reformulation of policies impacting on the agricultural sector. The government should carefully examine the inadvertent damage to the capacities of research and development institutions because of budgetary and staff cuts under the Economic and Structural Adjustment Programme. There is also a need for improved incentives to attract and retain outstanding scientists in these research and development institutions” (Smith *et al.*, 2012: p.139). An area of agricultural importance requiring urgent intervention is crop diseases and pests management. The focus should be those currently affecting the agricultural sector, such as the armyworm and those that may come about as a result of climate change. According to the FAO (2016), army-worms have invaded and destroyed entire fields in the SADC countries’ of Zambia, Malawi, Zimbabwe and South Africa. These caterpillars are South American specie (Figure 2-2), referred to as fall army-worm and are known for destroying entire fields within hours, as they move as an “army”.

Figure 2-2 A Caterpillar, South American specie, commonly referred to as fall army-worm (source CNN, 2017)

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As recent as 2016, a number maize fields in South Africa, were severely damaged from a caterpillar's attack. According to (DAFF, 2016), the outbreak poses a real threat to maize crops in South Africa. Fall Army-worm invasions were detected in North West Province, and the northern parts of Limpopo Province. The affected zones are by far the largest maize producers in the region. According to Reuters News (2017), the South American species is harder to detect and eradicate than its African counterpart. This is because the fall army-worm burrows into the plant (Figure 2-3), whereas the African army-worm burrows from outside, thus the fall army-worm will often only be seen when coming out after the damage has already been inflicted. They can easily build resistance to chemical control (Figure 2-4) because their burrowing activity makes contact with the chemicals difficult.

Figure 2-3 A picture of the damage an army-worm can cause to maize in this undated file photograph (Source: AFP, Undated)

Figure 2-4 Agricultural officials spray pesticides on maize plants affected by the fall army-worms in Keembe district, Zambia. (Source: Reuters, 2016)

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2.15. Chapter Summary

In this chapter, the literature shows that climate change and variability are an already occurring reality that is expected to impact agricultural production across the entire globe. The literature also shows that the projections and models are useful tools to assess impacts of climate change on crop production. The impacts of climate variability and change on maize production at different scales (international, continental, regional and national) were discussed. The climatic conditions of Limpopo Province and the effects of temperature and water stress on crop growth were described.

A review of the South African climate change policy landscape and influences was also undertaken. Adaptation responses to future climate variability and change by the producers, government and non-governmental organisations and the adaptive capacity at farm level were discussed. The chapter also highlighted the predicted climatic changes for South Africa through regional scenarios highlight extreme heat and floods, droughts and heavy rains, erratic and/or declining rainfall patterns, as the likely outcomes of climate change. The literature indicates that all these scenarios have an impact on agriculture, affecting the vulnerable populations and food security.

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Chapter 3 RESEARCH METHODOLOGY

3.1. Introduction

The purpose of this study was to determine maize producer's vulnerability and assess the impact of climate variability and change on maize production in the Makhuduthamaga Local Municipality. The aim of this chapter is to provide a detailed description of the methods employed to accomplish the objectives of this study. The chapter starts by providing a description of the research design, in order to enable the researcher to acquire reliable, valid data and results. This chapter further outlines sampling methods adopted and provides a comprehensive description of the data collection instruments used.

This study made use of both primary and secondary data sources such government documents, books, journals and scholarly articles. Followed by the narrative of data analysis techniques and presentation of the results. Reliability, validity and ethical considerations are also described.

3.2. Research design

According to De Vaus (2002) research design is the overall strategy chosen to integrate the different components of the study in a coherent and logical way, thereby, ensuring that the researcher will effectively address the research problem. The research design of the study adopted a mixed methods approach. Quantitative research is used in empirical investigations, with focus on objective measurements and statistical or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques. Quantitative research is used to "determine cause-and-effect interactions between variables" (Burns and Grove, 2005:23). This approach focuses on gathering numerical data and generalizing it across groups of people or to explain a phenomenon (Babbie, 2010; Bless and Higson-Smith, 2000).

On the other hand, qualitative research is primarily exploratory research, used to gain an understanding of underlying reasons and opinions. It provides insights into the problem or helps to develop ideas or hypotheses for potential quantitative research. It is also used to uncover trends and to produce detailed explanations to reliably describe actions (Ingleton and Seymour, 2001). These methods were adopted, as they are flexible and can be used to

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provide an understanding of issues, and exploration of issues as new information becomes, available instead of sticking with one method throughout the process.

For the purpose of this study, mixed method research design was adopted, to enable the researcher to acquire reliable, valid data and results. The researcher used exploratory research design to evaluate the extent of maize producers' vulnerability to the impacts of climate and variability change and their associated adaptation measures, whilst descriptive statistics design was used to establish the impact and magnitude of climate variability and change on maize production in the Makhuduthamaga Local Municipality. Exploratory research helps determine the best research design, data-collection method and selection of subjects. Generally exploratory research does not lead to conclusive answers, but rather clarifies the scope and nature of a problem and proposes possible solutions.

3.3. Sampling

Prior to distributing questionnaires and conducting interviews, the selection of respondents is necessary. A representative sample of the total populace is necessary, from which the data will be collected. The Makhuduthamaga Local Municipality is characterised as rural, mostly under the control of traditional land ownership. It is made up of 189 settlements, with a population of 274 358 in 65 217 households, with 24,803 agricultural households (The Local Government Handbook, 2016). A household is defined as agricultural "when at least one member of the household is operating a holding (farming household) or when the household head, reference person or main income earner is economically active in agriculture" (Organisation for Economic Co-operation and Development, 2001).

The sampling method used was convenience and purposive. Purposive sampling method uses the researcher's judgement in selecting the respondents and covered most of the identified producers in the Makhuduthamaga Local Municipality and covered the uniform or homogeneous characteristics of producers. At 95% confidence level, the sample size of 76 households from 24 803 households represents a confidence interval of 11.2. These methods were preferred because they are valid even when there is no sample frame, are generally less complicated to undertake and minimize the preparation costs of the survey with the respondents chosen, based on their relative ease of access.

Closed-ended questionnaires were employed to elicit background information and information about climate variability and change, maize production, education, occupation, experience in farming, access to extension services and climate variability and change

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perception. In order to enable the respondents to give elaborate responses, semi-structured questions were employed.

3.4. Data collection and instruments

3.4.1. Interviews

A qualitative approach was adopted: semi-structured interviews were used to collect the primary data. Semi-structured interviews are credited as appropriate for the collection of primary data on a topic that lacks previous studies in that study area (Kitula, 2006). The information collected from the respondents included their experience in farming, source of income, and perception of the occurrence of climate variability and change and soliciting responses on what respondents believed are the impacts of climate variability and change on maize production in the study area.

The interviews were directed at maize producers and other key informants with direct working relationship with producers in the study area. These key informants included provincial agricultural officers, extension officers and research officers. This approach was guided by the philosophy and methodology of Participatory Rural Approach (PRA). PRA is an extractive research methodology consisting of "systematic, semi-structured activities conducted on-site with the aim of quickly and efficiently acquiring new information about rural life and rural resources" (Kitula, 2006).

The target population was selected for the interviews for the purpose of evaluating maize producers' vulnerability to the impacts of climate variability and change, examining adaptation measures adopted by producers, government and non-governmental agencies in response to climate variability and change in Makhuduthamaga Local Municipality. The semi-structured interviews with a predetermined set of semi-structured, yet flexible questions (Appendix B), was administered. This approach allowed the researcher to diverge from the guide to pursue other details of interest to the study. From these key informants (Appendix C), the following information was sourced: (a) farmers' perception of climate variability and change variability (b) Information on policies and strategies that are in place to deal with climate variability and change (c) Difficulties that producers experience in relation to climate variability and change, (d) The main adaptation measures implemented by the producers and the provincial department to deal with the challenges of climate variability and change.

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3.4.2. Questionnaires

The quantitative part of the study adopted the distribution and administration of the questionnaires to the producers. These methods are explorative and descriptive by nature (Hoedoafia, 2014). A total of 76 questionnaires with closed and semi-structured questionnaires (Appendix A) were distributed to the producers during focus group sessions. Six focus group sessions were conducted with each group made up of between 10 – 14 producers. The focus group participants were selected using purposive and convenience sampling method. Members of the community who were available, willing to participate and provide useful information formed part of the focus groups. A written informed consent detailing the aim of the study and the potential benefits to the participants was sought prior to commencement. The participants were assured that their privacy and confidentiality will be protected.

The advantages of focus groups are that they are relatively flexible, low cost and provide quick results. Furthermore, participants may feel free and comfortable in a group setting, rather than in an individual interview. With all admistered questionnaires returned, the study had response rate of a 100%. Data was collected from September to November 2017 at the Makhuduthamaga Local Municipality, Limpopo Province, South Africa.

The questionnaire was developed and used to solicit biographical and socio-economic information (age, gender, educational level), and producers perception and views regarding climate variability and change. Information on access to agricultural extension support; the impact of climate variability and change on maize production was also sourced. The questionnaires were administered through a drop and pick methodology. Through questionnaires data is quickly collected and used for many purposes. One of the advantages of administering a questionnaire is that it is easy to test validity and reliability (Creswell, 2009).

The researcher, together with extension officers involved in providing extension services to producers in Makhuduthamaga Local Municipality, distributed the questionnaires. Extension officers were also involved in the process because they had history, knowledge of the study area and overall familiarity with the producers. During this study, the purpose and significance of their involvement were explained to the respondents.

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3.4.3. Rainfall and Temperature data

Rainfall and Temperature data for the period under review (1985–2015) from selected weather stations was obtained from the South African Weather Service (SAWS). Monthly rainfall and temperature data from nine weather stations shown in Figure 3-1 were used to analyse relationships, patterns using multiple regression analysis. Stations with uninterrupted data at >90% up to date records for the period under review were selected for the analysis. The World Meteorological Organization recommends a period of 30 years or longer as ideal for studies dealing with long-term changes.

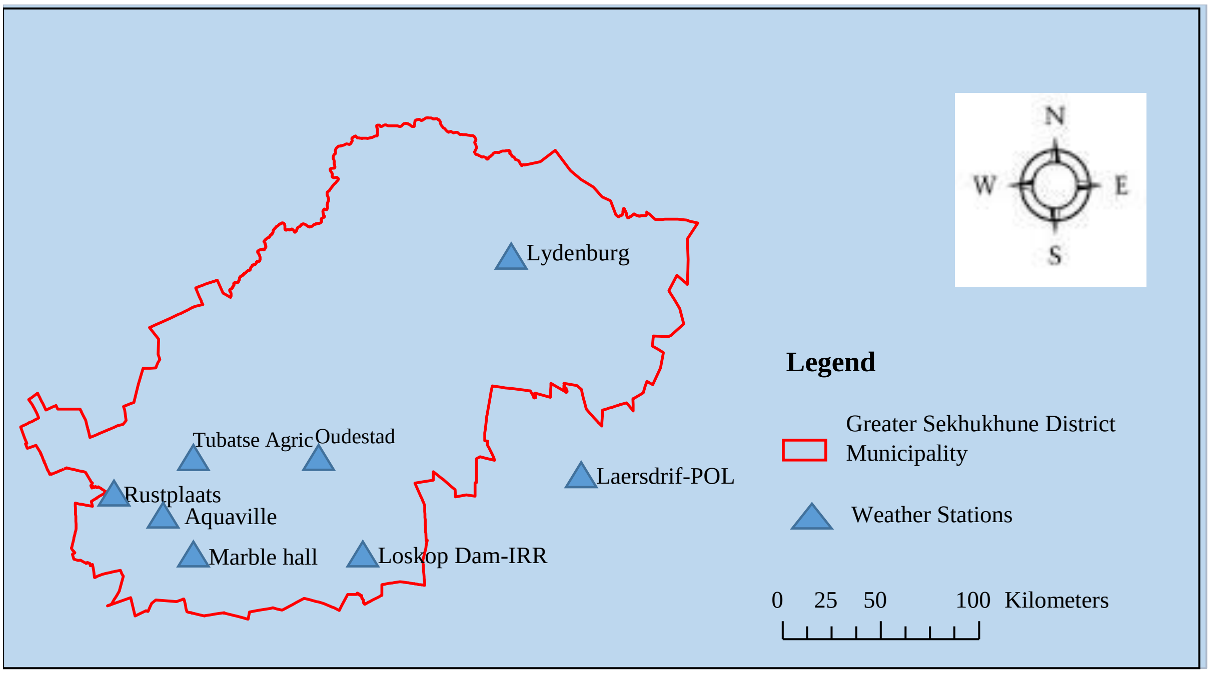

Figure 3-1 Spatial distribution of the weather stations in Makhuduthamaga Local Municipality

3.4.4. Maize yields data

Data on maize production for the period under review was obtained from the South African National Department of Agriculture. Both the standard deviations and the sample variance (equations 3.1 and 3.2) were used to analyse and demonstrate maize yields variation, calculated against the total growing area and rainfall for the study area in both spatial and temporal terms.

$$S_x = \sqrt{\frac{\sum x^2}{n} - \bar{x}^2} \qquad \text{Eq. 3.1}$$

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$$S^2 = \frac{\sum(x - \bar{x})^2}{n-1} \qquad \text{Eq. 3.2}$$

Where x represents each value in the population;

X= the mean value of the sample;

Σ =the summation (or total); and

n-1 is the number of values in the sample minus.

3.5. Data Analysis Techniques and Presentation

To achieve the objectives of this study, the following tools of analysis were employed.

3.5.1. The impact and magnitude of climate variability and change

Three analysis tools were employed to determine the impact and magnitude of climate variability and change on maize production. These are trend analysis, multiple regression and coefficient of variation statistics

3.5.1.1. Trend analysis

Trend analysis is defined here as an approach to analysis which collates data and then attempts to discover patterns, or trends, within that data for the purposes of understanding or predicting behaviours (Rae, 2014). Despite being a robust analysis tool; trend analysis has some limitations. For instance, small populations and changes over a period affect the appropriateness and use of trend analysis. Therefore, such conditions of interest should be considered (Raina, 2013).

However, trend analysis is more effective and valuable when dealing with the prediction of future values using historical data for comparison to actual current values (Raina, 2013). Trend analysis is also advantageous for detecting variances (Meals, 2011). To overcome some of these limitations; Polynomial function, which gave the best fit in terms of the magnitude of the coefficient of determination (R^2), was chosen and presented

Trend analysis of the rainfall and temperature trends during growing seasons was undertaken, to define the magnitude of changes across period of production. Trend and

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patterns were determined using Linear, Exponential and Polynomial functional forms with graphs and trend lines.

3.5.1.2. Multiple Regression Analysis

Multiple regression analysis was utilised to establish the magnitude and impact of climate variability on maize production. Multiple regression analysis allows the examination of the relationship between multiple variables in a quantifiable manner. This technique is often used where there are multiple explanations (independent variables /co-variates) for an outcome (dependent variable usually denoted by Y).

There is generally an accepted preferential use in research of crop simulation models in studying the effects of climatic variables on crop yield. However, minor changes in the climatic variables, specifically in temperature are often excluded (Schlenker *et al.,* 2008). According to Lobell (2005 and 2008), the use of regression analysis techniques based on historical yield data and climate data is important because they are relatively accurate for prediction of changes in yield due to climate variables.

To determine the relation of maize yield with rainfall and temperature, this is to find out whether as one variable increases, the other tends to increase (or decrease). This test of relation was summarized with the P, value where a significant relationship means that different values of the independent variable cause different values of the dependent. The significance threshold of the P value was set at $< .05$. To decide whether this relationship is positive or negative, the correlation coefficient (or "r") was determined. The R value varies between -1.0 to 1.0, thus the results will be read as follows: the r value closer to +1 or -1 indicates that how closely two variables are associated. When the r value is near 0 it indicates no association between the variables. If the r value is positive, it means that as one variable is directly related to the other. If the r value is negative it means that as one variable gets larger, the other gets smaller.

3.5.1.3. Coefficient of variation

The coefficient of variation statistics (CV) was used to determine the mean variation in the time series of rain days, maize yields, annual rainfall, onset and cessation. The higher the coefficient of variation, the greater the level of dispersion and relative variability around the mean will be expressed as a percentage. The lower the value of the coefficient of variation, the results or estimate will be interpreted as more precise. The trends in the time series of

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these parameters (annual rainfall, maize yields, rain days, onset and cessation) were determined using regression analysis.

Knowledge and understanding of how rainfall characteristics (amount, rainfall days, and rainfall onset and rainfall cessation) and variability affect maize yields is vital. Rainfall onset and cessation dates, usually regarded as the beginning of the growing season and end of the growing season, were determined using the classification of Olaniran (1984).

3.5.2. Vulnerability to climate change

The IPCC (2014) defines vulnerability to climate change as “the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt”. The expected impacts, risks and the adaptive capacity of a sector to the effects of climate change are determined through the concept of vulnerability assessment. Vulnerability assessment methods are broad, ranging from global and national quantitative assessments to local-scale approaches.

According to Preston *et al.* (2009) there are no rules to determine the boundaries of a system, and thus the selection of boundaries in a vulnerability assessment should be established according to the objectives of the study and the interests. The suitability of a chosen assessment method depends on the adaptation management issue under consideration, including the time and scale, the variables involved and economic and governance aspects.

The vulnerability assessment method (VAM) used was derived from the work of Schroter and Metzger (2004). It is a simple conceptual function describing how the different elements of vulnerability are related to each other. The three components of vulnerability, according to the IPCC (2014) definition are: sensitivity, exposure and adaptive capacity. Thus vulnerability is a function of exposure, sensitivity and adaptive capacity as shown in Equation 3.3 (Fontaine and Steinman, 2009 & Metzger and Schroter, 2006).

$$\boldsymbol{V = \frac{E + S}{A}} \qquad \boldsymbol{Eq. 3.3.}$$

Where

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V= Vulnerability

E= Exposure

S= Sensitivity and

A= Adaptive capacity

Vulnerability is given as a range from zero to one. A value of zero indicates low vulnerability, whilst a score of one indicates extreme vulnerability Table 3-1 illustrates the vulnerability ranges and their description

Table 3-1 Vulnerability indicator scoring system: Fortaine and Steinemann (2009)

Vulnerability range	**Vulnerability description**
0 - 0.2	Low vulnerability
0.21 – 0.4	Moderate vulnerability
0.41 – 0.6	High vulnerability
0.61 – 0.8	Very high vulnerability
0.81 – 1	Extreme vulnerability

The variables for vulnerability that is adaptive capacity, sensitivity and exposure are themselves a function of some variables. Consequently; before computing vulnerability, exposure, sensitivity and adaptive capacity needs to be computed. Schroter and Metzger (2004) used a range of sub-variables some of which do not apply in this context. Therefore, the equations had to be adapted to ensure relevance and fit for purpose. A full vulnerability assessment includes all ecosystem services and the potential impacts as a function of global change on ecosystems as a function of sensitivity and exposure. These were not included in the vulnerability assessment, thus the adapted formula

- **Exposure**

The description will be based on a five level Likert-type scale (1932) (Bertram, 2012), that assumes that the strength/intensity of experience is linear, i.e. on a continuum from low to extreme , and makes the assumption that exposure can be measured. The Likert scale named after Dr. Rensis Likert, a sociologist at the University of Michigan, who developed the technique to foster a means of measurement of psychological attitudes in a “scientific way”. Specifically, he sought a method that would produce attitude measures that could reasonably be interpreted as measurements on a proper metric scale, in the same sense that we consider grams or degrees Celsius true measurement scales (Uebersax, 2006).

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The formula is given as:

$$E = \frac{Es + Vc}{2} \qquad Eq. 3.4$$

Where

E= Exposure

Es= Extension services

Vc= Variable climate

- **Sensitivity**

IPCC (2012) defines sensitivity as “the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding)”. Adaptation has the capacity to change the sensitivity by changing a system’s state. The equation for sensitivity is given as;

$$S = \frac{A + G + El + Cf + Vc}{5} \qquad Eq. 3.5$$

Where

A= Age

G= Gender

El= Education level

Cf= Crop Failure

Vc= Variable climate

Sensitivity is described using a five level Likert-type scale, ranging from low sensitivity to extreme sensitivity, with the mid-point showing no effect. The five elements are combined and averaged to attain the sensitivity indicators. A score of Zero indicates low sensitivity whilst a score of one indicates extreme sensitivity

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- **Adaptive capacity**

The IPCC (2007) defines adaptive capacity as "the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies". Adaptation to the changing climatic conditions is a factor of the capacity to plan, design and to implement options or measures while understanding the determinants of adaptive capacity has become crucial for effective responses (Smith *et al.,* 2010). The equation for sensitivity is given as:

$$Ac = \frac{Si + Pps + I + Pi + Drcv + Cr}{6} \qquad Eq. 3.6$$

Where
Si= Supplemental irrigation
Pps= Planning planting seasons based on the first rains
I= Intercropping
Pi= Production inputs
Drcv= Drought resistant crop varieties
Cr= Crop rotation

Adaptive capacity is described using a five level Likert-type scale, ranging from low adaptive capacity to extreme adaptive capacity with the mid-point showing no effect. The six elements are combined and averaged to attain the adaptive capacity indicators. A score of Zero indicates low adaptive capacity whilst a score of one indicates extreme adaptive capacity

3.5.3. Adaptation measures to climate variability and change

The data on chosen adaptation measures from interviews and discussions will be analysed using adoption ranking, cross tabulations and frequency distributions. Adoption ranking is a participatory research technique that allows analysing and identifying preferences by respondents. The respondent decides what is critical to them and their environment. Thereafter, the respondents rank their preferences in regards to their perceived importance. This method assists in starting discussions on possible solutions.

Cross tabulations were used to examine connections and influences within the data that were not being deceptive when analysing total survey responses. Cross tabulation were

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merely data tables that presented the results of the entire group of respondents as well as results from sub-groups.

Frequency distribution included creating of a frequency table as a way of summarising and organizing the data. This was done by recording every possible score of the respondents as a column of numbers and the frequency of occurrence of each score. The table showed the number of frequency with their percentages. The information confined in the frequency table was converted into a form of graphs.

3.6. Ethical considerations

To protect the respondents' privacy, the researcher obtained informed consent from them to participate voluntarily in the study (Appendix D). They were assured that their information would not be misused to embarrass or humiliate them. Only data absolutely necessary for achieving the objectives of the study would be obtained. To promote awareness of ethical principles and issues in conducting research activities while using animals or people in the research study, ethical clearance was sought and obtained from the university ethics committee.

3.7. Reliability and validity

Reliability is defined as the consistency in and ability to repeat the findings. A reliable measure does not fluctuate randomly. According to Gwimbi and Dirwai (2003) a good research design should be valid and be able to produce reliable results. In this study, the research design was chosen to construe the vulnerability of maize producers to climate variability and change and how these are addressed and the main adaptation measures implemented by the various role players.

Validity is the ability of an instrument to measure a concept accurately to ensure that any observed differences are true and not the result of random errors (Polit and Beck, 2008). This study ensured that the data was reliable by using mixed methods research design accordingly. To ensure such reliability, field work was done and pictures were used to supplement the data.

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In this study, content validity was determined thorough extensive literature search to base the contents of the questionnaire and interview guides. To avoid biased responses from the questionnaire study, a number of measures were taken, including the following: providing the appropriate syntax, language, and content in phrasing the questions; standardizing the time aspect, memory effects, question order and number of response options. As in Hoedoafia (2014), the questionnaires were pre-tested randomly to five (5) households before administering them, to ensure validity and reliability of data gathered.

Generalisation of findings in relation to the population and whether similar findings can be obtained at other times and places is dependent on the degree of confidence. The relationship between the researcher and respondents is important in achieving valid results. Generally, first interactions are formal and the influence is low (Madyise, 2003). On the other hand, if respondents are acquainted with the researcher, this might influence the information provided and lead to biased results (Creswell, 2009).

3.8. Chapter Summary

The multidimensional nature of climate variability and change, impacts and associated adaptation measures, have shown that research on climate variability and change cannot be achieved by a single research perspective. A mixed research design approach is necessary, in order to address the objectives of the study and the research questions. This chapter provided information on the data collection instruments and the sample selection techniques. Descriptive statistics was conducted. Furthermore, regression techniques analysis was utilised to determine the association between variables to make a meaningful prediction on primary data collected from the study area in Makhuduthamaga Local Municipality, Greater-Sekhukhune District, Limpopo Province. The results of the study are discussed in detail in chapter 4.

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Chapter 4 RESULTS AND DISCUSSION

4.1. Introduction

This chapter presents the findings of the research on the impact and magnitude of climate variability and change on maize production in the Makhuduthamaga Local Municipality as well as adaptation measures adopted by producers, government and non-governmental agencies in response to climate variability and change. This chapter will also give an account of the results of the review of National Agricultural legislations, policies and other relevant strategies.

4.2. The impact and magnitude of climate variability and change

4.2.1. Seasonal rainfall variability and trends

The trend of the total seasonal rainfall for all the stations in Makhuduthamaga Local Municipality shows extensive variations in seasonal rainfall across all weather stations. Results indicate that the average annual rainfall is at 555.1 mm and has in some years been drastically low, with rainfall totals of below 400 mm. The lowest rainfall totals of 266.2 mm and 362.5 mm were recorded in the years 2003 and 2005. Annual rainfall totals exceeding 600 mm were recorded in a period of ten different years (33%) of the study, wherein the height was in 1996 at 802.1 mm, shown in Figure 4-1.

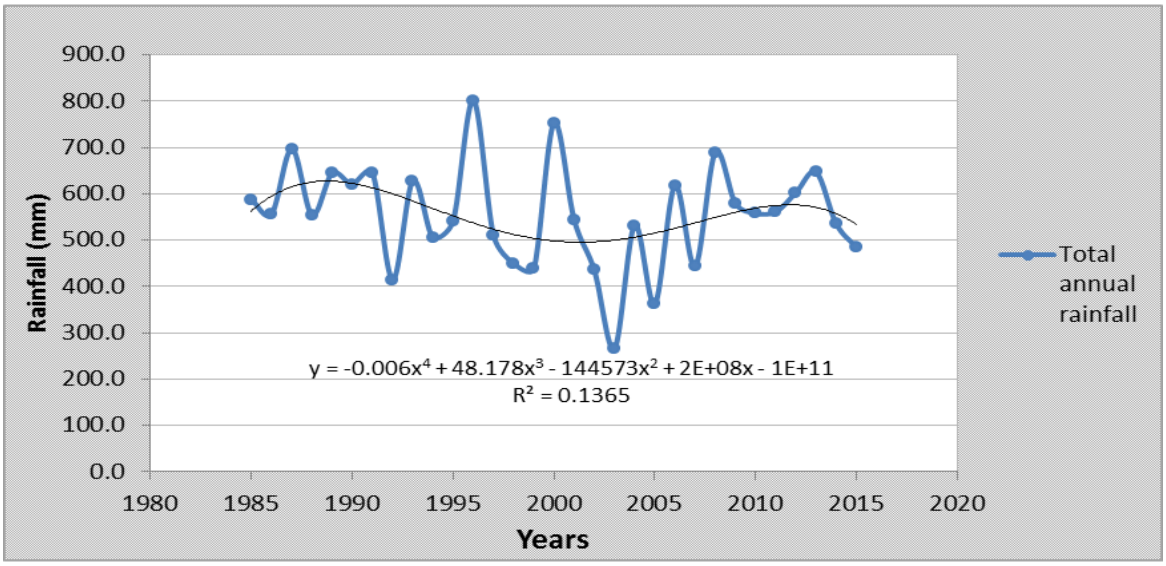

Figure 4-1 Total annual rainfall for Makhuduthamaga Local Municipality, 1985-2015

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Based on the average seasonal rainfall, several years with rainfall in access of 450 mm per annum show that the water requirements for the life cycle of a maize crop will be met without negatively affecting production. In years with rainfall totals below 450 mm per annum; the maize crop is more likely to be negatively affected due to water deficits (du Plessis, 2003).

Rainfall onset and cessation in the study area occurs during late September and early October and March and early April. On further analysis, rainfall onset can be differentiated between wet, dry and normal years. The years with rainfall onset dates between 17 and 27 September are classified as wet years; those years with dates between 28 September and 08 October are average/normal years, while those with rainfall onset dates from 09 September are classified as dry years (Olaniran, 1984). Using this classification, 61% (19 of the years) of the years fall within the class of average/normal years, while 32% (10 of the years) are wet, years with only 6.5% (2 of the years) classified as dry years.

In the study area, maize is a biannual crop; the onset of rainfall has an impact on yields. According to Moeletsi *et al*. (2011a) and Umar (2011), the date of occurrence of either the rainfall onset or cessation plays a vital role in defining the start and end of the growing season. Research shows that producers are able to plan and align their planting to coincide with rainfall onset to assist plant growth periods that are likely to be affected by water deficits and avoid the risk of crop failure (Ati *et al.*, 2002).

The implication on crop production is that during the wet years, producers benefit from early rains by planting at the earliest rainfall onset in September and October. In this study, the risk of crop failure due to false rainfall onset during the early stages of growth and development was not countered for. During the dry years rainfall starts late and delays the start of the growing season. Furthermore, the dry years normally demand that producers use various varieties of maize that are drought resistant or early maturing maize varieties.

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Table 4-1 Statistical analysis for rainfall characteristics and maize yield

Year	Maize Yields (ton/hec)	Total annual rainfall (mm)	Rainfall days	Rainfall onset	Rainfall cessation
1985	N/A	587.4	57	28-Sep	15-Mar
1986	1.8	557.2	55	05-Oct	01-Apr
1987	1.3	697.6	70	30-Sep	27-Mar
1988	2.17	554.5	63	03-Oct	22-Mar
1989	1.62	644.6	66	27-Sep	29-Mar
1990	2.65	620.5	59	23-Sep	02-Apr
1991	0.61	645.3	61	28-Oct	05-Apr
1992	1.29	414.5	39	07-Oct	16-Mar
1993	2.09	628.1	62	25-Sep	01-Apr
1994	1.18	505.4	51	01-Oct	22-Mar
1995	3.25	541.7	55	29-Sep	28-Mar
1996	2.25	802.1	76	17-Sep	11-Apr
1997	2.45	510.5	49	04-Oct	24-Mar
1998	1.47	449.9	45	02-Oct	18-Mar
1999	3.01	438.2	44	30-Sep	20-Mar
2000	2.22	752.4	71	20-Sep	05-Apr
2001	2.5	544.0	57	27-Sep	22-Mar
2002	2.72	435.4	46	01-Oct	17-Mar
2003	2.88	266.2	34	26-Oct	03-Mar
2004	2.76	531.8	49	03-Oct	10-Mar
2005	3.5	362.5	37	11-Oct	17-Mar
2006	2.4	617.9	58	30-Sep	23-Mar
2007	4	443.3	40	08-Oct	11-Mar
2008	5.2	689.3	66	24-Sep	06-Apr
2009	5	579.4	60	28-Sep	30-Mar
2010	5	558.1	61	01-Oct	27-Mar
2011	4.8	561.3	55	03-Oct	22-Mar
2012	5.5	602.6	58	26-Sep	19-Mar
2013	6.1	646.9	63	25-Sep	07-Apr
2014	7.7	535.5	55	02-Oct	26-Mar
2015	5.8	484.4	49	05-Oct	28-Mar
Mean	3.174	555.1	55.194		
Standard Deviation	1.729	113.0	10.248		
Coefficient of Variation	54.47%	20.35%	18.57%		

The statistical analysis of rainfall characteristics in the study area indicates that rainfall is highly variable at 20.35%, and thus poses a risk to maize production. According to research, high coefficients of variation are not uncommon in semi-arid environments. Kosgei (2009) and Lynch *et al.* (2001) have reported a coefficient of variation of annual rainfall of up to 26%

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in Limpopo Province and North West Province. Maize yields and food security are susceptible to rainfall characteristics, especially under rain-fed conditions (Oruonye *et al.,* 2016). They are important for improved decisions concerning choice crop varieties to grow in the study area. This view is supported by Olanrewaju (2006), who identified rainfall onset and cessation as important components of moisture resources status for determining the potential of various crops.

4.2.2. Rain days

The highest number of rainfall days observed during the period under review was 76 days in 1996. On the other hand, the lowest number of rain days of 34 was recorded in 2003. The highest and lowest rain days observed in the study show a significant positive relationship ($r^2>0.5$ and P<001) with annual rainfall (Figure 4-2). Thus the number of rainfall days has the greatest influence on the total rainfall received. This conclusion concurs with the observation by Ojo, *et al*. (2001), that the patterns of mean rain days generally follow a similar pattern with mean rainfall amounts.

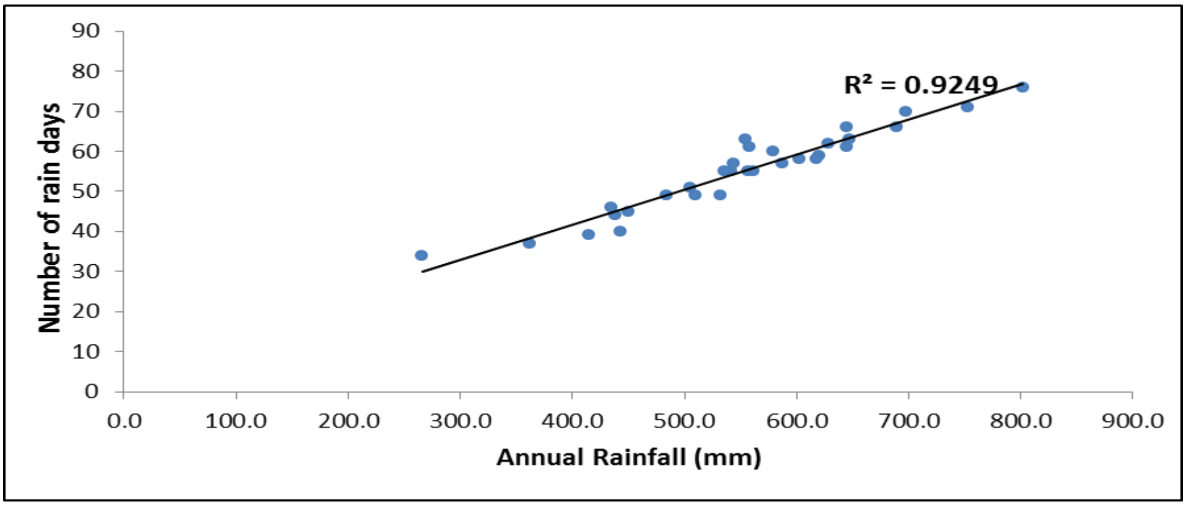

Figure 4-2 Relationship between annual rainfall and number of rain days

The rain days' standard deviation of 10.25 days' and coefficient of variance of 18.57% (Table 4-1) characterises the annual occurrences of rainy days for the period under consideration as consistent. Thus, the implication for optimum maize yields is that the amount of rainfall should be evenly distributed over an appropriate numbers of days during its growing season.

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4.2.3. The Coefficient of variability of climatic parameters

The coefficient of variability of the rainfall characteristics shows that maize yield per hectare records (Table 4-1) an overall high coefficient of variability of (54.47%), followed by total annual rainfall (20.35%), with rain days presenting the least variability (18.57%). This implies that the rain days may be predictable, with total annual rainfall only slightly variable in the study area. The impact of climate variability and change is more distinct in drier environments (Omoyo *et al.,* 2015). The cumulative effect of other climatic and non-climatic factors not considered in this study could be responsible for the high coefficient of variability of maize yields in the study area.

4.2.4. Temperature variance

The results also revealed that variance in temperature have increased during the period under review, with r^2>0.5 or 39.7%. Thus, the changes in temperature are becoming more predictable. The average maximum temperatures have been higher in between the period 2006-2015 (at 26.8°C) than in the preceding decade (1995-2004) when average temperature was 26.5°C (Figure 4-3). Tshiala *et al*. (2011) reported a rise of 0.12°C in the mean annual temperature per decade, over the 50 year period. The authors of the same study also reported seasonal trends that revealed variability in the mean temperature increase of about 0.18°C and 0.09°C per decade in winter and summer respectively. The results point to climate variability has been more an imminent threat maize production.

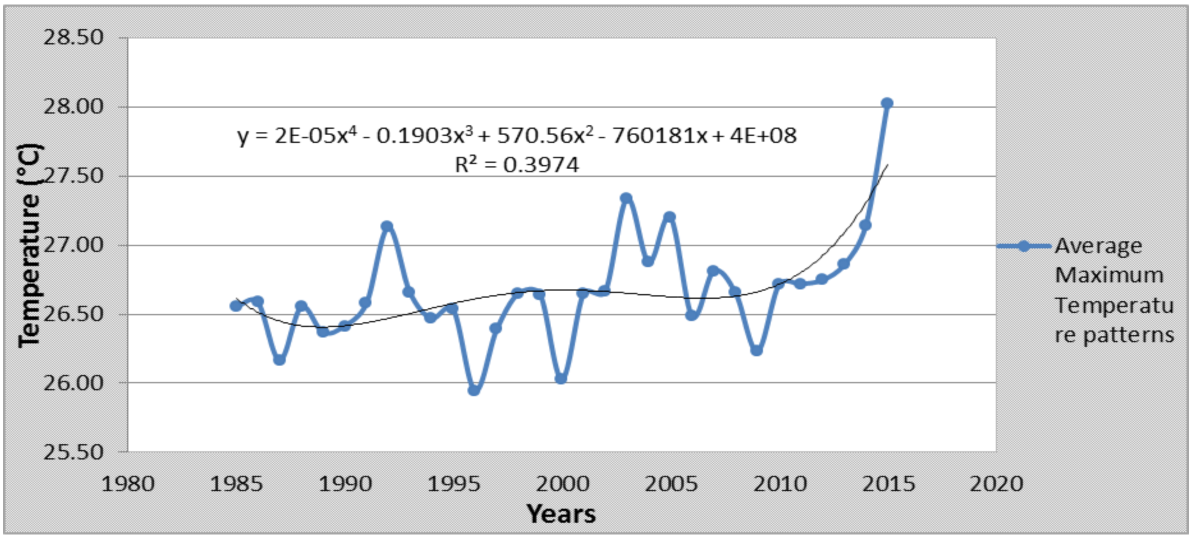

Figure 4-3 Temperature patterns for the years 1985–2015

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4.2.5. Maize yields variability

The standard deviations (SD) and sample variance were used to analyse and demonstrate maize yields variation calculated against the total growing area for the study area. Overall, the study has showed significant variability of maize yields both spatially and temporally. The relationship was both positive and significant, with $r^2>0.5$. Over the study periods, maize yields have continually varied and are closely linked with the climate variables. Despite a clear fluctuation in yields, the results demonstrate a clear raising trend which may not be accounted for by climate only. The implication is the total area grown and variations in rainfall tend to influence maize yields during the period under review.

The most unproductive year by yield per hectare planted over the study period was in the 1991/92 growing season. The production rate was 0.61 tons per hectare. This production rate is in line with the national rate of 0.67 tons per hectare (Figure 4-4). In the same year, a total rainfall of 414.5 mm was received in 39 days. The figures represent the third lowest total rainfall and rainfall days, respectively, during the period under review (Table 4-1). The most productive season was the 2014/15. The production rate was 7.7 tons per hectare. This success might be attributed to the total rainfall received (535.5 mm) and a variety of possible adaptive responses being adopted by farmers to deal with climate variability. This includes the use of more drought-tolerant crops, planning, access to climate variability and change information and infrastructural development.

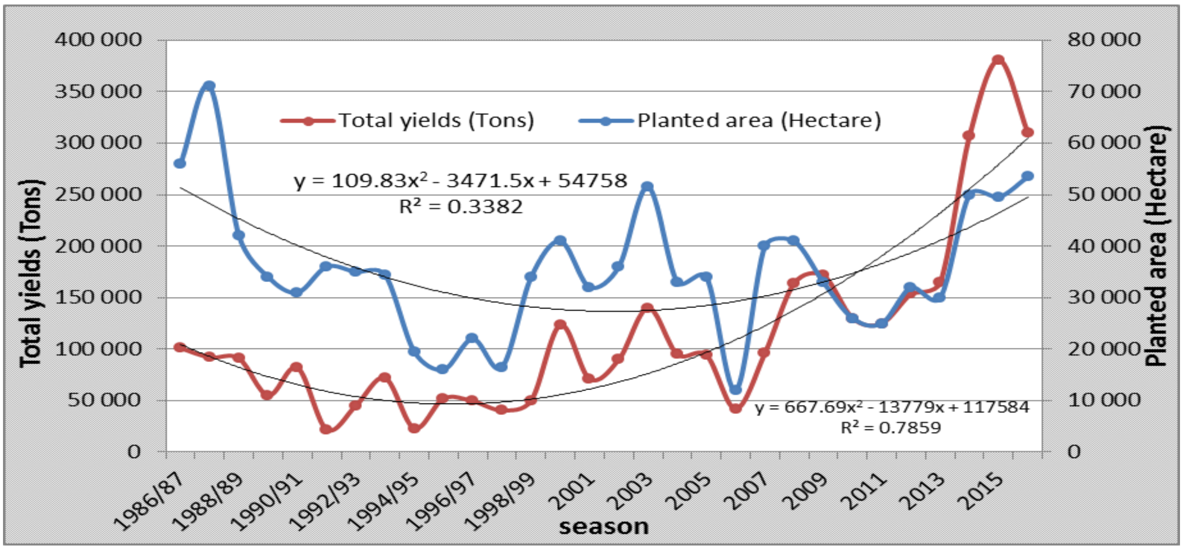

Figure 4-4 Maize Production: Total yields against planted area in Limpopo Province, 1985 - 2015

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For the period under review, the variations observed in the average rainfall and rain days were not related to the variation in yield of maize. The results revealed a weak relationship between annual rainfall, rain days and maize yields (r^2>0.5, P>0.05 and r^2>0.5, P>0.05 respectively). Summary statistics are shown in Figure 4-5.

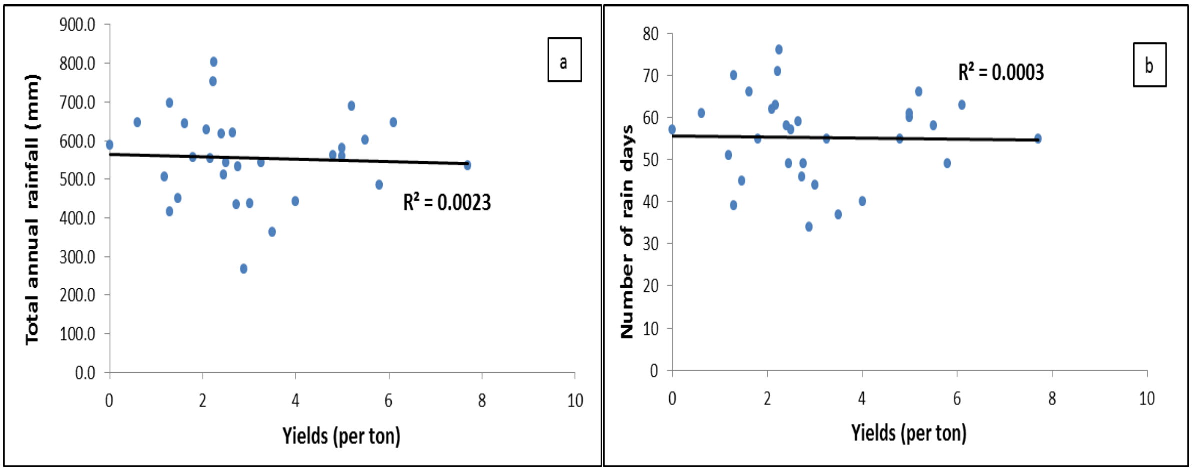

Figure 4-5 Relationship between rainfall characteristics and maize yields

During the period under review; the variations in rainfall did not significantly influence variation in maize yields. In other words, the results revealed a weak relationship between annual rainfall and maize yields. On further analysis of the data, it was concluded that these results are skewed by several major outliers in 1996, 2003 and 2005. Maize yields outliers were identified in 2013, 2014 and 2015. These were constrained to provide unbiased results. The results revealed positive but insignificant relationship between annual rainfall, rain days and maize yields (r^2>0.5, P>0.05 and r^2>0.5, P>0.05 respectively). Summary statistics are shown in Figure 4-6.

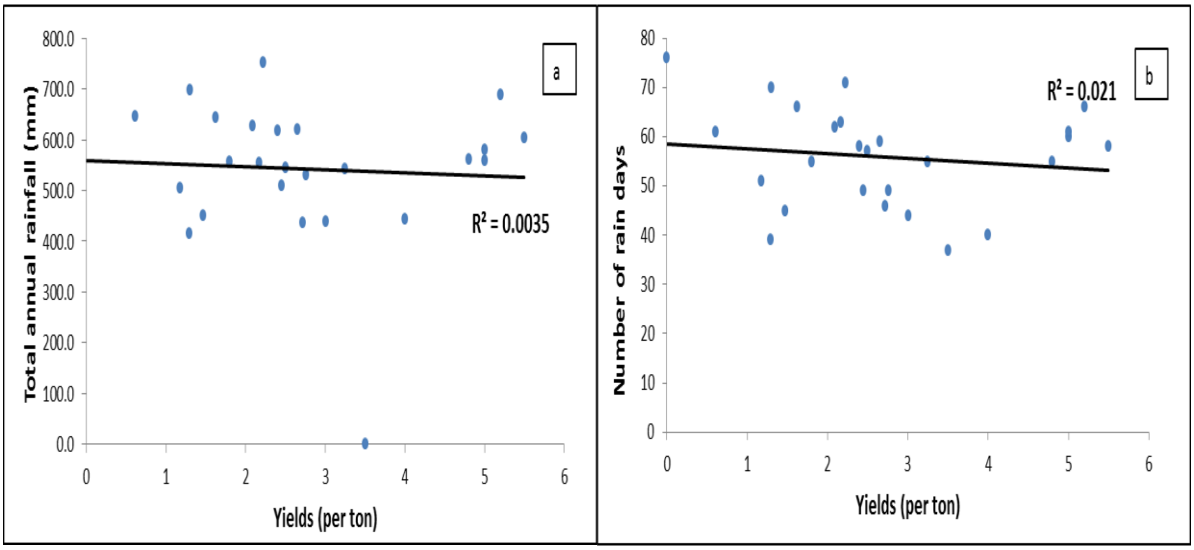

Figure 4-6 Relationship between rainfall characteristics and maize yields (Constrained outliers)

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Apart from the influence of annual rainfall variability on maize production, factors such as temperature might influence the maize production. Changes in temperature affect maize production through increased evaporation in the soil, leading to lack of the required moisture for the maize plant to develop and reach maturity (germination to vegetative growth and later grain filling), while the proliferation weed and pests is an unfavourable condition for maize production (du Plessis, 2003).

Moeletsi (2010) noted that maize is resilient to adverse conditions and erratic rainfall that affect productivity negatively. However, constant yield variability of maize is likely to have the most effect on small-scale and subsistence farmers who are in agricultural marginal areas, such as in Limpopo Province, who must also attempt to farm under water-stressed conditions. In the context of the municipality being in a rural setting, this leads to high vulnerability of poor-resourced households, unemployment, lack food-security and an increase in the cost of maize.

4.2.6. Impact of climate variability and change on maize production

Climate variability and change has a distinct impact on maize producers, with 57 (75%) of the respondents indicating that climate variability has had high impact on maize production with 51 (67%), listing climate change as having a high impact on maize production (Figure 4-7). The findings concurs with Blignaut, *et al*. (2009), who found that in Limpopo Province, maize was grown almost exclusively under rain-fed conditions, with conclusions that a 1% rainfall decline can lead to a 1.1% decline in maize yields during the summer season. Producers operate in varied environments, with erratic weather events and variable climate, compelling producers to re-examine their approaches to productions.

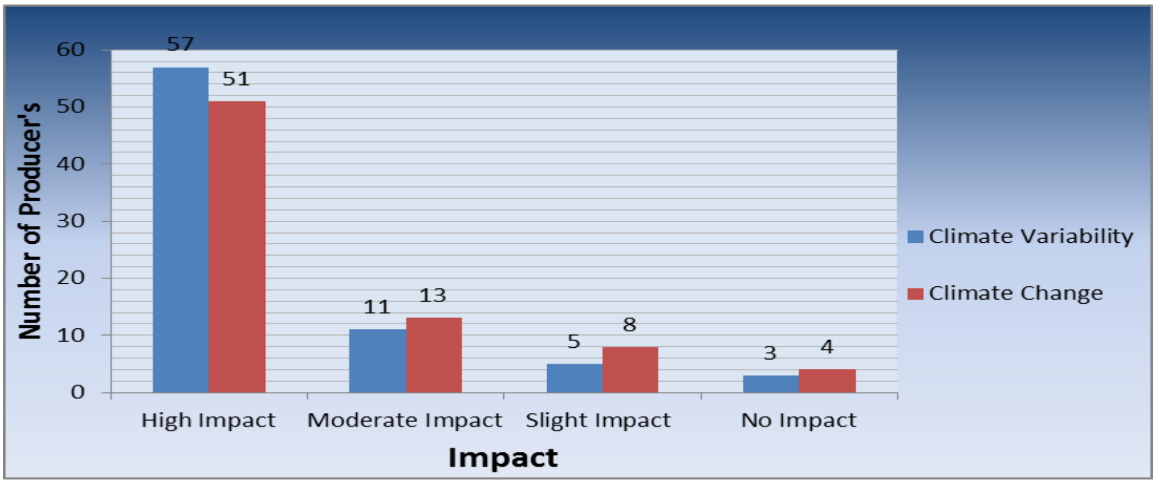

Figure 4-7 Impact of climate variability and change on maize production

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Most rural communities of Limpopo Province focus on growing maize for economic or food security reasons (Mpandeli *et al.,* 2005). It is evident that the changing climate will have an impact on agricultural production dependent on climatic conditions and the quality of the rainfall received. The context in which maize production is taking place in Limpopo Province necessitates that adaptation measures are adopted to mitigate the impacts of climate change.

4.3. Rainfall variation and trends during maize growing seasons

The standard deviation and the coefficient of variation (CV) statistics were employed to determine rainfall variation. The descriptive statistics in Table 4-2 show that the main growing season (October-January) mean rainfall is higher than during the secondary growing season in all the weather stations (Figure 4-8). The results also showed that rainfall during the growing seasons has been variable.

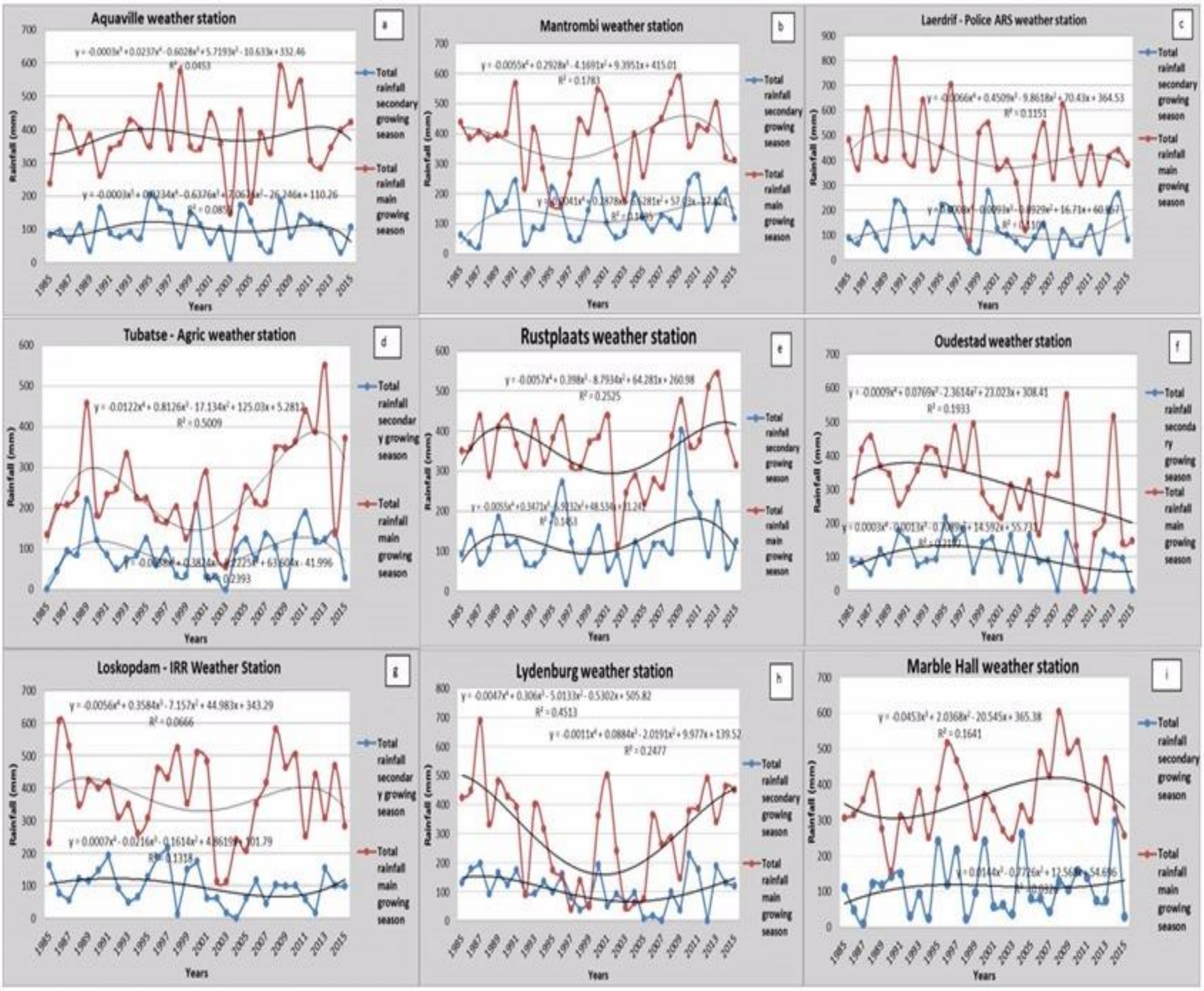

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Figure 4-8 Rainfall variations during maize growing seasons across all stations

The standard deviation and coefficient of variation (CV) statistics were employed to determine rainfall variation. The descriptive statistics shown in Table 4-2 show that the main growing season (October-January) mean rainfall is higher than during the secondary growing season in all the weather stations (Figure 4-8). The results showed that rainfall during the growing seasons has been variable.

For the main growing season, the station with the most rainfall is Laersdrif – Police with $r^2>0.5$ or 11% variation in rainfall. The station recorded a mean seasonal rainfall of 645.5 mm. Tubatse Agric is the driest with 250.3 mm, $r^2<0.5$ or 50% variation in rainfall. During the secondary growing season, the results ($r^2<0.5$) show that Mantrombi station was the most wet, with a mean seasonal rainfall of 128.8 mm, while Tubatse Agric is the driest (with 89.3 mm). This result marks Tubatse Agric as the driest out of all the weather station in both the main and secondary growing seasons.

Variations in annual rainfall can be identified in all weather stations; the secondary growing season CVs are higher than of the main growing season (Table 4-2). Marble Hall weather station had the highest variability, with a CV of 26.5% for the secondary growing season, while Rustplaats weather station displayed the lowest variation, with a CV of 19.4%). For the main growing season; Rustplaats weather station had the highest CV of 8.3% while Lydenburg weather station had the lowest CV of 3.8%. Variability existed in temporal inter-seasonal rainfall in all the weather stations, ranging 250.3-428.5 mm for the main growing season and 371–601 mm for the secondary growing season.

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Table 4-2 Variations in annual rainfall during the growing seasons

				Standard deviation (mm)		Coefficient of variation	
Stations	Mean of main growing season (mm)	Mean of secondary growing season (mm)	Mean annual rainfall per station (mm)	Main growing season	Secondary growing season	Main growing season represented as (%)	Secondary growing season represented as (%)
Mantrombi	382.1	128.8	602.9	22.1	28.1	5.8%	21.8%
Marble hall	361.5	110.8	562.5	26.0	29.4	7.2%	26.5%
Loskop Dam – IRR	377.2	98.0	576.7	30.6	24.9	8.1%	25.4%
Laersdrif – Police	428.5	112.6	645.5	31.1	29.0	7.3%	25.7%
Lydenburg	303.0	106.7	491.4	11.7	22.9	3.8%	21.5%
Tubatse Agric	250.3	89.3	431.5	18.8	20.8	7.5%	23.3%
Rustplaats	358.2	128.1	600.3	29.6	24.8	8.3%	19.4%
Aquaville	379.0	101.4	579.4	24.6	22.7	6.5%	22.3%
Oudestad	311.1	98.9	505.8	18.7	25.1	6.0%	25.3%

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4.4. Temperature variation and trends during maize growing seasons

An analysis of the maximum temperature trends has shown general variability during both the main growing season and secondary growing season. The results indicated that in the main growing season; eight weather stations showed an upward increase and warming in the maximum temperature. Laersdrif was the only weather station [Figure 4-9 (c)] recorded a slight decline during both growing seasons in the maximum temperatures at -0.0161°C for the main growing season and -0.0237°C for the secondary growing season. Oudestad weather station recorded the greatest increase in the maximum temperature, for both growing seasons. Trend lines show a warming of up to 0.0618°C for the main growing season and 0.0544°C for the secondary growing season [Figure 4-9 (f)]. Both Aquaville [Figure 4-9 (a)] and Tubatse-Agric [Figure 4-9 (d)] weather stations recorded a decrease in temperatures during the secondary growing season. Overall, all weather stations have showed an increasing trend in temperatures during both growing seasons.

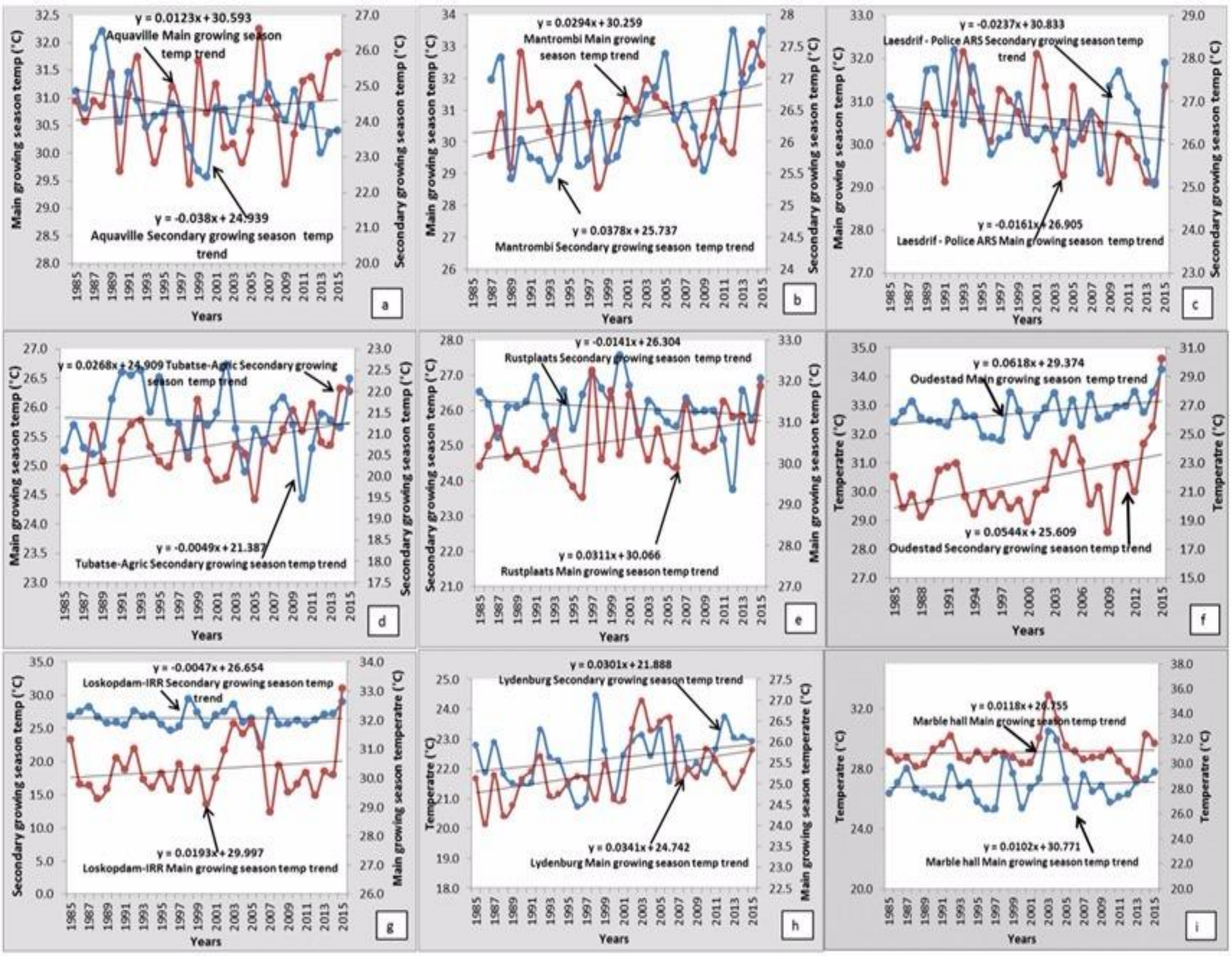

Figure 4-9 Maximum temperature trend during maize growing seasons across all stations

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4.5. Producers' vulnerability to climate variability and change

4.5.1. Producers' exposure to climate variability and change

The indicators used for determining exposure are variable climate and extension services. The VAM results indicate that producers have very high exposure to climate variability and change with a score of 0.8 (Table 4-3).

Table 4-3 Climate variability and change exposure indicators

Indicator	Score	Description
Variable climate	1	Extreme exposure
Extension services	0.6	High exposure
Sensitivity	**0.8**	**Very high exposure**

According to DEA (2013) temperatures over Limpopo Province are projected to increase drastically, reaching a regime never observed before in the recorded climate of the region. At regional level, evidence from Kruger and Shongwe (2004) show a strong warming trend in southern Africa. Furthermore; agricultural extension services are meant to provide producers with appropriate information on a variety of issues regarding crop production, such as new alternative methods, technologies, marketing, adaptation strategies and technical skills.

Based on the VAM results, it is expected that producers in the study area will be exposed to extreme weather events which can cause significant crop and income losses. As such, producers' needs to play an active role in addressing their vulnerability to challenges related to climate variability and change.

4.5.2. Sensitivity to climate variability and change

The demographic indicators used in determining sensitivity indicator included age, gender, farming experience, crop failure and variable climate (Table 4-4). VAM indicates that producers have extreme vulnerability to variable climate, whilst crop failure exposes producers to high levels of vulnerability.

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Table 4-4 Climate variability and change sensitivity indicators

Indictor	**Score**	**Description**
Age	08	Very high sensitivity
Gender	04	Moderate sensitivity
Farming experience,	0.8	Very high sensitivity
Variable climate	1	Extreme sensitivity
Crop failure	0.7	Very high sensitivity
Sensitivity	**0.74**	**Very high** sensitivity

Most producers interviewed were male (61.8%), with female producers making up 38.2%. The age group of most producers was above 46 years (77.6%), whilst those in the youngest age group of 18 – 30 only constituted 6.6%. This implies that in the study area, maize production is mainly in the hands older members of the community. Thus, age and gender are important factors in the sensitivity of producers. Several studies (e.g., Deressa *et al.,* 2011; Gbetibouo, 2009) on producers' ability to adapt to changing climatic conditions show that adaptation is influenced by factors such as gender, education, age and farming experience.

In terms of experience, the majority of maize producers had active experience in farming of between 11 and 29 years (57.8%), whilst the most experienced group of producers with over 30 years' experience represented 21% of the population. It can therefore be deduced that farming experience builds the confidence of farmers to engage in maize production. This category of farmers, as other studies show (e.g., Ibrahim *et al.,* 2015, and Oduniyi 2013) have accumulated a wealth of knowledge in adapting to change in the climate and thus thrive in maize production.

4.5.3. Adaptive capacity to climate variability and change

The VAM results show that supplemental irrigation is the highest adaptive indicator among the producers whilst intercropping is the lowest indicator of adaptive capacity (Table 4-5). The results show also producers have moderate adaptive capacity, with a value of 0.38.

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Table 4-5 Climate variability and change adaptive capacity indicators

Indictor	Score	Description
Supplementary irrigation	0.65	high adaptive capacity
Planning planting seasons based on the first rains	0.4	Moderate adaptive capacity
Intercropping	0.2	Low adaptive capacity
Production inputs	0.38	Moderate adaptive capacity
Crop rotation	0.3	Moderate adaptive capacity
Drought resistant crop varieties	0.4	Moderate adaptive capacity
Adaptive capacity	**0.38**	**Moderate adaptive capacity**

The low value for moderate adaptive capacity finding correlate with Maponya (2012), who found that only 21% of producers had implemented an adaptation measure to mitigate against the perceived impact of climate variability and change. According to Tshiala (2011), producers in Limpopo Province might be able to adapt to rising temperatures and reduced amount of rain, as well as timing and frequency. However, the frequency of extreme weather events occurrence may negatively affect them. Furthermore, the ability or inability of producers to adapt has negative implications for food security, loss of income and competition for scarce resources. Thus it is imperative for producers to make a concerted effort to proactively take up adaptation measures.

4.5.4. Vulnerability to climate variability and change

Vulnerability is a function of exposure, sensitivity and adaptive capacity (e.g. Fontaine and Steinman, 2009, Metzger and Schroter, 2006). Their average values were used in calculating the overall vulnerability of producers. Exposure was scored the highest at 0.8, sensitivity of producers was 0.74. Adaptive capacity was low with a value of 0.38. Using VAM, vulnerability was determined to be 4.05. Thus, the based on the vulnerability indicator scoring system, the study found that producers have high vulnerability to climate variability and change.

Climate-change-related impacts on maize production are varied in terms of magnitude and localities. Some studies show that climate change exposes rural based subsistence farmers to new and unfamiliar conditions (Leichenko and Obrien, 2000). Furthermore, erratic rainfall patterns and increasing temperatures without adaptation strategies pose a risk to agricultural production. This is expected to intensify producers' vulnerability to climate variability and change (Atedhor, 2016). However, producers are not passive participants in climate change

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and actively adapt to these changes. Others continue to face increased vulnerability, particularly in the developing world such as sub-Saharan Africa (Thornton *et al.,* 2006; Chagutah, 2010).

4.6. Adaptation measures to climate variability and change

4.6.1. Maize Producers

The results of the cross-tabulation showed that 33% of female producers and 59% of male producers opted for the use of supplemental irrigation. In both genders, the age group 46 – 60 was the most active across all age groups. This age group shows the highest adoption of supplemental irrigation (Table 4-6). In addition, crop rotation is the least adopted measure among both female and male producers. The results also show that 21% of female producers have adopted crop rotation whilst 28% of males adopted the same measure (Table 4-7). Furthermore, 18% of producers amongst the age group 46 – 60 indicated they did not adopt crop rotation; the same age group was still represented the highest adopters at 13.2%

Table 4-6 Adoption of supplemental irrigation by producers

Supplemental irrigation	**Age of Producers**				
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
Female	**2.63%**	**7.89%**	**18.42%**	**9.21%**	**38.16%**
No	0.00%	1.32%	3.95%	0.00%	5.26%
Yes	2.63%	6.58%	14.47%	9.21%	32.89%
Male	**3.95%**	**7.89%**	**31.58%**	**18.42%**	**61.84%**
No	0.00%	0.00%	2.63%	0.00%	2.63%
Yes	3.95%	7.89%	28.95%	18.42%	59.21%
Grand Total	**6.58%**	**15.79%**	**50.00%**	**27.63%**	**100.00%**

Table 4-7 Adoption of crop rotation by producers

Crop rotation	**Age of Producers**				
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
female	**2.6%**	**7.9%**	**18.4%**	**9.2%**	**38.2%**
No	2.6%	2.6%	7.9%	3.9%	17.1%
Yes	0.0%	5.3%	10.5%	5.3%	21.1%
male	**3.9%**	**7.9%**	**31.6%**	**18.4%**	**61.8%**
No	0.0%	3.9%	18.4%	11.8%	34.2%
Yes	3.9%	3.9%	13.2%	6.6%	27.6%
Grand Total	**6.6%**	**15.8%**	**50.0%**	**27.6%**	**100.0%**

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The results show that up to 46% of maize producers are engaged in farming on a fulltime basis; 26.3% are farming on a part-time basis and up to 14.5% also have salaried employment. According to some studies (e.g. Maddison 2006, 2007; Anley *et al*., 2007) improving employment are key to increasing the adoption of various adaptation measures. Furthermore, educated and experienced producers are expected to have more knowledge and information regarding climate change and adaptation measures to use in response to expected adverse climatic challenges.

The results also show that the majority of producers were in the age group of 46 – 60 or above (77.6%). This group is the most active across all adopted measures identified, both in terms of uptake and non-uptake of adaptation measures (Appendix E). This implies that in the study area maize production is mainly in the hands older members of the community. This might also imply that younger producers are less likely to choose an adaptation measure.

Producers' uptake of adaptation measures to cope with climatic variability and change has indicated that many have opted for more than one adaptation measure. According to the adoption ranking results, supplemental irrigation was ranked as a preferred method of adaptation amongst all producers by 92% of the respondents. The use of production inputs was ranked second whilst Crop rotation was ranked the lowest (Table 4-8). Factors that influence the adoption of adaptation measures as illustrated were related to either access to information (such as rainfall projection, availability of drought tolerant seed varieties) or extension support at farm level. Up to 83% of the producers acknowledged during discussions that in the absence of this support, they relied on farming experience, available finances and knowledge on their environment to select an adaptation measure deemed suitable to the existing weather conditions. Examples of identified adaptation measures in use by the producers interviewed are discussed further below:

Table 4-8 Adoption ranking of adaptation measure to climate variability and change

Adaptation measure	Number of producers	Ranking	Percentages
Supplemental irrigation	70	1	92.11
Production inputs	61	2	80.26
Intercropping	57	3	75.00
Planning planting seasons based on the first rains	45	4	59.21
Drought resistant crop varieties	40	5	52.63
Crop rotation	37	6	48.68

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4.6.2. Supplementary irrigation

In the Makhuduthamaga Local Municipality, the challenge of water deficit was caused by erratic rainfall limits and dry land crop production. These place a burden on producers due to the need to install expensive irrigation infrastructure, such as boreholes, to help with supplemental irrigation in the early growing stages of crops. About 92% of producers currently rely on access to water for irrigation purposes, to increase producers' resilience to climate variability. However, Cunha *et al*. (2014) identified lack of capital as a factor that inhibits the adoption of irrigation as an adaptation measure. Supplementary irrigation is used to balance low levels of rainfall in the study area.

Rainfall-dependent small-scale producers are more susceptible to the impact of climate variability and change than large-scale well-resourced commercial farmers. With sufficient water supply, large-scale irrigated production is least vulnerable to climate change (Schulze *et al.,* 2010; DAFF, 2013). Irrigation farming has the potential to contribute to food security and income of participating homesteads. In the context of erratic rainfall and water shortages, in order to counteract the effects of limited moisture in agricultural management, the South African Climate Change Response strategy (2012) advises that climate change adaptation measures must focus on changes in agricultural management practices, such as a change in planting dates and cultivar choice.

4.6.3. Intercropping

The resources deprived producers dependent on rain-fed agriculture of their livelihoods in Sub-Saharan Africa (Burney & Naylor, 2012). In regions facing poverty and food insecurity, in which agricultural production is dependent of rainfall, producers practice intercropping as a traditional means of increasing yields, land productivity and crop variety for diversified income and food security (Kamruzzaman & Takeya, 2008). About 75% of the producers interviewed in the study adopted intercropping as an adaptation measure. In most rural parts of Limpopo Province, maize and beans crops are staple food and complementary crops. In crop management, the establishment of the ideal number of plants is crucial for obtaining maximum yields, while cropping different species together. Typically, cereal crops such as maize and sorghum are dominant crop/plant species, whereas legume crops such as beans, cowpea, groundnut and soybean are the associated plant species (Willey, 1990).

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4.6.4. Crop rotation

Crop rotation refers to growing two or several crops in the same space in sequence or a definite sequence of crops grown in successive years (or successive seasons) on the same land, the sequence being repeated again and again. According to Grain SA (2016), a crop rotation programme is a planned cycle of crops that will be planted in a particular land in a defined order over three to five years and even longer, if fallow periods or pasture are included in the cycle. Different crops have different nutrient requirements and affect soil balance differently. Some, such as maize and tomatoes, are heavy feeders that rapidly deplete soil nutrients. Thus, continuous planting of such crops in the same plot/area of soil will deplete nitrogen and phosphorus more rapidly.

Up to 49% of the producers indicated that they practiced crop rotation as an adaptation measure. These methods were viewed as advantageous for resource-constrained producers who have unproductive nutrient deficient land, coupled with insufficient rainfall. A study by Ogoke *et al*. (2009) in other parts of Africa demonstrated the benefits of crop rotation with legume crops, as it improves the supply of nitrogen through symbiotic fixation, which reduces the artificial nitrogen fertilizer requirement for the following planting cycle. Drought and low soil fertility are just some of the factors that impact agricultural production systems in southern Africa (Sanchez, 2002). Improved soil conditions are likely to enhance the productivity of both legumes and cereals in the early growing phases.

4.6.5. Use of production inputs

Eighty percent of producers use adjusts production inputs to improve soil fertility. Nutrient deficiencies, especially of the major nutrients (such as nitrogen and phosphorus), are among the major constraints for enhancing crop yields (Yadav *et al.,* 2000). The availability and cost of chemical fertilizers for most rural-based resource-constrained producers pose a challenge in addressing soil fertility (Bumb *et al.*, 2011). Thus, it is vital to apply fertilizers to maintain acceptable levels of soil fertility and to minimize loss, in order to realize consistent maize yields production, more sustainable production systems are required (Li *et al.,* 2009). Several studies have suggested the use of organic inputs (e.g. leguminous green manure and crop residues) to sustain crop yields through the provision of nitrogen to crops and to maintain soil fertility (e.g., Papastylianou, 2004; Zoumane *et al*., 2000).

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4.6.6. Use of drought resistant varieties

In order to address the challenges posed by drought induced by low levels of rainfall over a lengthy period, it is vital for producers to understand what drought is and the impact on agricultural production. Generally, conditions such as dried crops, dust storms, and starving livestock are associated with drought. The IPCC (2012) defines drought as a “period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion”. For the purpose of the current study, the drought implies low precipitation during the growing season that impinges on crop productivity. Unlike most hazardous weather conditions, drought is not always obvious and may be several years in the making, arising from gradual loss of moisture in the soil through evaporation or the loss of surface water sources due to the lack of rainfall (Moola, 2010). Climate change is expected to exacerbate this problem.

The Drought Tolerant Maize for Africa Project has contributed towards improving seed system in sub-Saharan Africa for the past nine years (2007–2015), through the development of drought-tolerant well-adapted maize hybrids and open-pollinated varieties, to help farmers across 13 countries in eastern, west and southern Africa, cope with drought constraints in maize farming.

Drought tolerance is a complex trait that is difficult to select for under-field conditions (Grain SA, 2016). The DAFF, ARC, LDA and farmer based non-profit organizations are engaged in research on drought-resistant maize varieties. These organizations offer support and expertise on the choice and use of cultivars, such as drought tolerance. Locally adapted maize varieties use both conventional breeding and genetic modification technologies. These organizations use local seed distribution networks to distribute the new drought-tolerant varieties at no additional cost to producers. The use of maize varieties is high among the producers but slightly lower (53%) than other measures adopted. These maize varieties are expected to assist producers to stabilise and produce substantial yields under moderate drought conditions. This is likely to have a significant impact on the food security, financial security and livelihoods of smallholder producers and their families.

4.6.7. Planning planting cycles based on the first rains

Maize is South Africa’s staple crop. Therefore, the size of the harvest is a key factor in food pricing and food security. Due to rainfall variability experienced in the maize growing regions

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of the country, rain-fed agricultural production has become exceptionally risky. Thus, the climate and adaptive capacity of producers can be considered as a critical factor responsible for year-to-year variations in crop yield.

The crop planting date as a climate change adaptation measure to lessen crop water stresses can contribute to enhance agricultural decision-making (Moeletsi *et al*., 2011a and Umar (2011). Producers require precise information on projected rainfall and temperature patterns ahead of the planting cycle, to enable better planning. During the discussions, it emerged that 59% of the producers use rainfall characteristics, such rain onset and intensity, to plan their planting cycles.

Ugwu (2015) cautions producers against planting based on the first rain, due to the risk associated with heat stress due to lack of effective rain. Should producers use the first rain to plant, the provision of sufficient water supply should be prioritised, to ensure that there is enough water for crops during dry spells. Planting can also be planned such that anthesis does not coincide with spells of lack of rain and unfavourable high temperatures.

4.7. Limpopo Provincial Department of Agriculture

For crop production such maize in marginal regions, climate change in the absence of adaptation measures is predicted to adversely impact production at local temperature increases of 2°C or more above late-20th-century levels, although individual locations may benefit (IPCC, 2007). As a means of adjusting and dealing with immediate and expected future climate change, the Department of Agriculture, through its research and extension services directorates, is engaged in research and implementation of the following adaptation measures: (a) Research on drought-resistant maize cultivars, (b) water conservation methods and rainwater harvesting technologies, (c) Promoting crop diversification; (d) Fertilizer application; (e) Mechanization in maize production (f) Education, outreach and (g) training of farmers on the issues of climate variability and change (h) connecting farmers to NGOs, as well as (i) Training and capacitating of extension services personnel on how to cope with ongoing climate variability and change.

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4.7.1. Agricultural extension services: provincial government's perspective

From the interviews with the Provincial Department of Agriculture representative, if was found that efforts are being made to provide producers with the required extension services in order to aid in dealing and coping with the challenges that come with climate variability and change. To this end, several programs have been initiated and implemented through-out the province. These include the following: (a) Capacity building of farmer organisations (b) Research and outreach (c) Soil and water laboratory services (d) Land care and (e) Agricultural engineering.

The responsibilities of the Provincial Department of Agriculture towards producers cannot be overlooked. The Provincial Department of Agriculture remains the custodian of agriculture; a critical economic sector, given that Limpopo Province is predominantly rural in nature. Agriculture is a critical sector, contributing to economic development, food security and employment prospects of rural areas of the province. While it was difficult to achieve total agreement from the department with the findings from the interviews with producers regarding access to extension services, it was accepted that perhaps "*more can be done to assist producers"* within the context of financial and skills constraints.

4.8. National programmes

South Africa, as a developmental state, is committed to imperatives of sustainable development and as such, is at times impeded by a lack of reliable long-term data at scales that are relevant to influence policy development at a national level. The alignment of climate change adaptation with existing government priorities and policy can meet multiple objectives and increase the efficiency of human and financial resources (Ziervogel *et al*., 2016).

According to the South African Second National Communication under the UNFCC (2008), "South Africa's efforts in climate change science and the science-policy interface to date have resulted in progress on: (a) The scientific understanding of climate variability and change on seasonal, decadal, and centennial time scales (b) The analysis and prediction of earth's climate system variability and change (c) Establishing a dialogue between scientists, policy-makers, and practitioners that facilitate the sharing of information for decision-makers concerned with climate adaptation, mitigation, and risk management".

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At a national level, there are several role players involved in the coordination, data management and curation, monitoring and or research for securing long-term and large-scale data sets related to climate change. The following have been identified (not exhaustive) as key role players in running such national programmes: (a) National Department of Water Affairs (b) National Department of Agriculture, (c) South African Environmental Observation Network and (d) National Department of Environmental Affairs. The scope of work required is far-reaching and is often also carried out by departments within universities, NGO's, national science councils and other relevant and competent bodies and/or platforms. Table 4-9 provides a breakdown of organisations that have been identified as being involved in high-level climate change research.

Adaptation to climate variability and change is evident in our social and economic systems, such as agriculture and forestry, which has developed to accommodate inherent temporal variates from normal conditions (Dessai and van der Sluijs, 2007). The findings point to evidence that several activities have indeed been implemented by both the government and non-governmental agencies, to ensure that producers and households are better-equipped and adapt to climate variability and change, to improve production, household food security and income. As such, many activities that have been implemented to ensure that the producers are able to cope with the adverse effects of the expected climate change and negative impact on maize production.

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Table 4-9 Organisations that are involved in climate change research

Level	Organisation	Primary Activities
National Level	Department of Water Affairs	Monitoring and Research
	South African Environmental Observation Network	monitoring, research, data curation and management
	Department of Environmental Affairs	Research
	Department of Agriculture	Monitoring and Research
Programmes led by governmental agencies	South African National Parks	Research
	South African Weather Services	Research, Observation and Monitoring
	Water Research Commission	Research
Programmes led by science councils	Council for Scientific and Industrial Research	Research, Observation and Monitoring, data curation
	Agricultural Research Council	Research, Observation and Monitoring, data curation
Programmes led by universities departments	University of Kwa-Zulu Natal	Research, Observation and Monitoring
	University of Cape Town	Research, Observation and Monitoring
	University of Pretoria	Research, Observation and Monitoring
	University of the Witwatersrand.	Research, Observation and Monitoring
	University of Stellenbosch	Research, Observation and Monitoring

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4.9. Adaptation measures implemented by non-governmental agencies

Arising from the discussions with producers, it became clear that there was evidence of formal links with non-governmental sectors that run programs that deal directly with the impact of climate variability and change on maize production, except for private investors interested in agricultural production. Further information regarding the private investor was not made available, as it was deemed to be sensitive to be divulged, for the purpose of the present study. This notwithstanding, assurance through the ethical clearance indicated that their information would not be misused to embarrass or humiliate them.

As discussed above, climate variability and change research is carried out by many organisations, including non-governmental sectors. However, not many have the capacity, skills and resources to contributions to awareness-raising. The most visible and key role players are advocating, campaigning and informing the public about climate change, sharing experiences and practical approaches, encouraging producers to use appropriate seed varieties, depending on weather conditions.

4.10. Chapter Summary

It is generally accepted in research that the climate variability and change phenomenon is a reality. In this chapter, the results are analysed and discussed. Maize yields and climate variables were used to describe the magnitude and impact of climate variability and change in Makhuduthamaga Local Municipality. Results indicated that rainfall and temperature are increasingly variable during the growing seasons and directly correlated with maize yields variations. Seasonal variations in rainfall and temperature tend to influence maize yields in the entire area.

This chapter also demonstrated that climate variability and change are expected to cause erratic weather, increased temperatures, and variations in precipitation patterns. This might lead to intensification of erratic rainfall, occurrence and magnitude of extreme weather events such as droughts and floods. However, there remain uncertainties in projections of climate variability and change impacts (magnitude and rate at different scales); these are expected to impact regions such as sub-Saharan Africa, leading to crop failure, hunger, and poverty.

The chapter also assessed the adoption of adaptation measures, to combat expected climate variability and change in other areas, where agricultural production is dependent on

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rainfall. Due to rainfall variability experienced in the maize-growing regions of the country, rain-fed agricultural production has become exceptionally risky. The results indicate that experience and age are influential characteristics to adaptation, as they are viewed as determinants in decision making regarding the choice of adaptation measures, to increase the resilience of producers to climate variability and change. With more experience, farmers are more likely to perceive the change in climate. Producers who have access to agricultural extension support are expected to adopt adaptation strategies to address the perceived changes in the climate because extension services as a source of information are critical when assessing the coping mechanisms.

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Chapter 5 DISCUSSION OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

This chapter reviews the main results and findings of the empirical analyses of the study, makes recommendations and concludes on the basis of the findings. The main aim of the study was to determine maize producers' vulnerability, assess the impact of climate variability and change on maize production in the Makhuduthamaga Local Municipality. The specific objectives were the following: (i) to establish the impact and magnitude of climate variability and change on maize production; (ii) to evaluate maize producers' vulnerability to climate variability and change, and (iii) to identify adaptation measures adopted by producers', government and non-governmental agencies in response to climate variability and change.

5.2. Discussion of the Findings

5.2.1. Climate variability and change

The results show that seasonal rainfall and maximum temperature, used as climate variables, very widely. As expected, the main growing season received higher rainfall compared to the secondary growing season. However, the results also showed higher rainfall variability during the main growing season than the secondary growing season, with a negative trend across several stations.

From the study, maximum temperatures have shown an upward increase of about 0.02°C since 1985 during the main growing season (October-January); eight out of the nine weather stations showed an upward increase and warming in the maximum temperature, and only Laersdrif weather station [Figure 4-9 (c)] recorded a decline during both growing seasons in the maximum temperatures at -0.0161°C for the main growing season and -0.0237°C for the secondary growing season. The Oudestad weather station recorded the greatest increase in the maximum temperature for both growing seasons. An upward warming trend by 0.0618°C for the main growing season and 0.0544°C for the secondary growing season was revealed [Figure 4-9 (f)]. The upward increase of temperature and the variability in season-to-season rainfall in the study area pose huge challenges for crop production. Subsequently, variations in climatic conditions have had vast impacts on the length of the growing season, maize yields and food security in the study area.

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The results appear to support the views by Omoyo *et al.* (2015) and Blignaut, *et al.* (2009), that the higher the temperature, the less rainfall is received. This negative trend is expected to have adverse climatic conditions and impact on agricultural production should the trend continue. The implication is that in cases where rural scale producers dependent rainfall for agriculture, with no adaptation strategies to the challenge of adverse effects of climatic changes and variability, the risk of crop failure is likely to be high.

5.2.2. Maize yield variability

Overall, the results showed significant variations in maize yields in the study area in spatial and temporal terms. High variability of inter-annual and intra-seasonal rainfall over most parts of southern Africa agricultural productivity is affected (Moeletsi *et al.,* 2012). Maize yields have over the study period constantly varied and is closely associated with climate variability. In a study in the Free State Province, de Jager *et al.* (1998) found that fluctuations in maize production were positively associated with rainfall variability. According to Akpalu *et al.* (2011) precipitation is an important driver of maize production. Thus, from the study results, it is evident that the variations in climatic variables tend to have a significant impact on maize yields in the study area for the period under review.

The unpredictability in CVs values reveals impacts of climatic variables on maize, with variability in maize yields related to the main growing season rainfall. Climate variability could affect maize production significantly. Consequently, maize yields show a general increasing trend despite a variable climate. It is hypothesised that this is due to improvements in crop varieties, technological advances and the uptake and access to climatic information. However, the increase in maize yields does not reach full potential because of the impact of climate variability and change.

5.2.3. Producers' vulnerability to climate variability and change

Exposure, sensitivity and adaptive capacity to climate variability and change render producers highly vulnerable to the impacts of climate variability and change. Furthermore, erratic rainfall patterns and increasing temperatures without supplemental irrigation pose a threat to producers' ability to produces sustainably and avoid crop failure and reduced yields. The changing climatic conditions are expected to exacerbate producers' agricultural vulnerability to climate variability and change (Atedhor, 2016). As such, producers are

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frequently exposed to extreme weather events which cause significant crop and income losses. As such, producers' need to play an active role in adapting to the challenges posed by climate variability and change. In addition, producers' choices of adaptation strategies are limited by available information and resources (Long, 1992).

Producers' vulnerability to climate change can be minimised through the timely adoption of adaptation measures (Schubert *et al.,* 2007). As such, the potential for agricultural adaptation at farm level is very high because adaptations arise from the farmers' perception of changed or changing conditions. From the study, the results indicate that the producers' perception of the occurrence of climate variability and change is high, as 65.7% of the respondents indicated that the state of climate is increasingly variable, whilst 59% indicated that the climate has changed over the study period. Maponya (2012) found that 54.7% of farmers believe that long-term temperatures are increasing.

5.2.4. Adaptation to climate variability and change

The results showed that 61.5% of the producers have implemented or adopted an adaptation strategy to cope with the perceived climate variability and change. According to Uddin *et al.* (2014) farmers' responses to the effects of climate change and adoption of adaptation strategies are influenced by their socio-economic characteristics, with knowledge of the farmers being the most influential. The results also show that most producers have adopted more than one adaptation measure. Several studies have indicated that the main effects of climate change will be felt by small rural farmers, mainly due to their lack of capacity to adequately adapt. According to Fosu-Mensah *et al*. (2012) only a small number take advantage of adaptation options.

Agricultural extension services are meant to provide producers with appropriate information of a variety of issues regarding production, such as new alternative methods, technologies, marketing, adaptation strategies and technical skills. The results showed that only 46% of the producers had access to extension services. A finding supported by a study in Limpopo Province by Maponya (2012) showed that 49% of the respondents had access to extension services. The high rate of access to extension services as a source of information is critical when assessing the coping mechanisms adopted by producers. The study underlined the relationship between the adoption of adaptation measures to address climate variability and change, as well as the independent variables such as age, gender, farming experience and education.

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5.3. Limitations of the study

Although this study contributes to the literature on the impact of climate variability and change on maize production in the Makhuduthamaga Local Municipality, the research findings are not exhaustive, like any other work. First the data used in the study did not include information on farmers' preparation of the soil/farm and inputs prior to planting. However, the assumption is that proper field management practices are employed, which impede the growth of weeds and the outbreak of pests. This information may be critical in assessing climate change impacts on maize production and could have facilitated the analysis and modelling of the potential crop failure at the different stages of the maize growth cycle.

Secondly, studying the impact of climate change on agriculture is a long-term study which would require ample resources, time and scientific instruments and methods. However, this study was constrained in a variety of ways, including the limitation of the funds, timing of the studies and adequate prior research training.

5.4. Recommendations

To ensure the impact of climate variability and change on maize production in the Makhuduthamaga Local Municipality is addressed to enhance/sustain maize yields and in view of the major findings and conclusions, the following recommendations are made for the consideration and/or adoption by Limpopo Province's Department of Agriculture, farmers and other relevant stakeholders who are interested in climate variability change issues. The research findings are not exhaustive and as such, they may require further research.

5.4.1. Intervention and adaptation strategies

To reduce the impact of increasing temperature and variable rainfall on maize production, investment in new technologies, such as irrigation, planting of drought-tolerant maize crop varieties, planning regulations and infrastructural development, should be prioritized as important adaptation strategies that would help farmers to avoid the impacts associated with climate change in the future. This could be achieved by prioritizing to intervention and adaptation strategies that target mitigation of decreased rainfall impacts, especially during

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the second growing season, which is associated with a drastic decrease in rainfall, as demonstrated in the present study

5.4.2. Access to extension services

Extension service is recognised as an important link between government and farmers; as such, it is generally expected of extension services to encourage farmers to adopt new technologies in place of traditional methods, improve skills and share, discuss and disseminate knowledge and information related to climate change issues. Tripathi and Mishra (2017) have shown the importance and role of extension services in providing information. Shongwe (2014) and Tripathi & Mishra (2017) argue that adaptation is a function of perception of the occurrence of climate change and its impacts and have concluded that this perception (correctly or incorrectly) depends on the knowledge and access to information. The role of extension services support should be properly communicated to the farmers so that they can embrace the opportunity of having extension agents around them (Maponya and Mpandeli 2012; Makapela, 2015).

5.4.3. Education on climate change adaptation

Precise information grounded in empirical research around the impacts of climate change should be distributed to the producers, in order for them to understand what climate change is all about and what potential impacts it has on their activities, food security, production yields and livelihood. Anley *et al*. (2007) identified education as a critical aid to reduce vulnerability to disasters and enhance adaptation to climate change. Muttarak and Lutz (2014) argue that education and accurate knowledge will bring about an increase in farmers level of awareness.

Farmers should be equipped with knowledge on climate variability and change, as well as the adaptation of measures to help them in their faming activities. Kumari *et al.* (2014) found that educated farmers are expected to have more knowledge and information about climate change and the agronomic practices that they can use in response. While spending on climate change adaptation tends to be focused on large infrastructure projects, such as flood defences and irrigation systems. Muttarak and Lutz (2014) suggest that investing in education could be a better way to reduce vulnerability to climate-related disasters. Different forms of information could be passed on using various sources, such as print and electronic media, as well as audio and visual aids.

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5.4.4. Policy Implication

While Government policies are comprehensive and elaborate in their response to climate change, as discussed in the literature review, there is an urgent need to address the support provided to extension support services, particularly in an area such as training, so that they are given requisite knowledge about climate change awareness and skills required by the farming communities. According to Hosenally (2011), in Mauritius the main cause of performance gap of extension officers was training, as only 39.3% of the extension officers claimed that training was not done at regular intervals. Ayele *et al.* (2002) emphases that the efficiency of extension services depends on extension professionals who are skilled, inspired, dedicated and quick to respond to the ever-changing needs of the producers either socially, economically and politically. They should be equipped with the necessary skills to disseminate information in a manner that producers will apprehend.

Another policy message emanating from this project is the critical need for the government through organisations such as the ARC, SAWS and extension services, to provide adequate climatic information services. This will ensure that farmers are well informed about expected rainfall and temperature patterns in the coming seasons to enable farmers an opportunity to plan more effectively around their planting dates, perform yields projection and required inputs. Moeletsi (2010) developed the Free State Maize Agro-climatological Risk Tool to provide agro-climatological risk information important to the production of rain-fed maize in the Free State Province. The tool is to be used by the farmers, extension officers and policy-makers. Such information from the tool is useful in providing valuable information to producers when planning for the coming season. Baethgen *et al*. (2003) suggest that the availability of climate and agricultural information helps farmers to make all-encompassing decisions in agricultural production

5.5. Areas of future research

- Future work should consider estimating maize yields, taking into consideration both intra annual and seasonal variations of climate change.

- Future studies should use time series data or panel data when assessing the impact of climate change on maize production

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- As noted in the research, the impacts of increased climate variability and change on producers' productivity and livelihoods are less clear because farmers are not passive players, but rather active 'agents' whose strategies and interactions shape the outcome of development within the limits of the information and resources available to them. It is recommended that future studies on the impact of climate change on agriculture should pay specific focus on the adaptation measures employed by farmers.

5.6. Conclusions

The scientific community has broadly acknowledged that climate variability and change phenomena are an occurring reality (IPCC, 2011; Shongwe *et al*., 2009; Stocker *et al*., 2013 and Zhang *et al*., 2015). The purpose of this study was to determine maize producers' vulnerability and assess the impacts of climate variability and change on maize production in the Makhuduthamaga Local Municipality. It also sought to identify adaptation measures adopted by producers', government and non-governmental agencies in response to climate change and variability. Rainfall (frequency, amount and distribution) and increasing temperature patterns in the study area are anticipated to increase the occurrence and magnitude of extreme climatic events, such as floods and droughts similar to those experienced in January, 2012 (Maponya, 2012).

The findings of this study correlates with other findings on the impact of climate change and crops in Limpopo Province, South Africa and other African countries. Furthermore, the findings show that a change in the amount of precipitation is the most important driver of maize yields (Blignaut, 2009, Ayanlade, 2009, Akpalu *et al.,* 2011, Omoyo *et al*., 2015). The effect of variations of temperature and rainfall on maize yields will be influenced by the magnitude and direction of each of the changes. These changes will pose a risk to food security and livelihoods in the rural communities of Limpopo Province. Producers

Producers are proactively adapting to climate change, thus reducing their vulnerability to the impact of climate. Agricultural extension plays an important role in encouraging farmers to adopt new technologies in place of traditional methods and improve skills, amongst others. Access to agricultural support and improved methods and seed technology appear to be some of the major challenges in the subsistence farming sector. In the current study, it was found that demographic households' profiles, such as age, farming experience and occupation, were important determinants in the adoption of adaptation measures. Notwithstanding these findings, there is no evidence of strategic and integrated actions

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taken by the development institutions and other relevant stakeholders to reduce the impact of climate change by enhancing adaptation mechanisms to climate change.

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7. APPENDICES

APPENDIX A: QUESTIONNAIRE SURVEY

Dear Respondent

My name is Selelo Matimolane, a Master's Degree student in the department of Geography and Geo-Information Science, School of Environmental Sciences at the University of Venda). As part of the requirement towards the fulfilment of my studies, I would like to undertake research on the impact of climate variability and change on Maize Production in Makhuduthamaga Local Municipality.

The study has the following objectives: (1). Establish the impact and magnitude of climate variability and change on maize production in the Makhuduthamaga Local municipality; (2). Evaluate maize producers' vulnerability to climate variability and change; and (3). Identify adaptation measures adopted by producers, government and non-governmental agencies in response to climate variability and change.

The study will seeks and attempt to answer the following questions:

(1). has climate variability and change affected maize production in the Makhuduthamaga Local Municipality; (2). What adaptation measures have producers adopted in dealing with the impacts of climate variability and change; (3). What is the scale of climate variability and change and how is maize production affected.

You are informed that the basis of this study is for academic purposes, however, as with such research, it anticipated that its findings will contribute to knowledge and influence policy at local, national and regional to assist to in decision making, planning and management of the climate change challenges, adaptation measures adopted by local communities.

As a respondent, your participation and assistance is requested to assist in this study as the survey forms an important part of data collection necessary for the completion off the study. You are advised that your opinions are strictly confidential, and only members of the research team will have access to the information, no data published in dissertations and journals will contain any information through which respondents may be identified. Your anonymity is therefore ensured.

For further details regarding the study, please see the respondent consent form.

Thank you for your participation

Selelo Matimolane (Master of Environmental Sciences -Geography) Candidate

Department of Geography and Geo-Information Science

School of Environmental Sciences

University of Venda

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SURVEY QUESTIONAIRE FOR FARMER'S

The questionnaire is divided into three different section containing questions with closed-ended questions whereby you select your answer from a given set of options by means of ticking in the box corresponding to your chosen answer and the other type of questions is open ended, whereby in your own words you give the answer in the spaces/s provided.

Name of Interviewer: ……………………………………………………

Date of interview: …………………………………………………………

Questionnaire number: ……………………………………………………

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT

1. Age

18 – 30 years	31 – 45 years	46 – 60 years	60 years and above

2. Gender

Male [ ] Female [ ]

3. Educational Level

No Formal Education	Primary School Education	Secondary Education	University Education	Post - Secondary Education	Other Type of Education

4. Farming Experience

>5 years	6 -10 years	11 – 20 years	21 – 29 years	<30 years

5. Occupation (Source of Income)

Farming (full-time)	Farming (Part-time)	Salaried Employment	Other Occupation

6. How long have you been growing maize?

0 – 3 years	4 – 7 years	8 years and above

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SECTION B: PRODUCERS PERCEPTION AND AWARENESS OF CLIMATE VARIABILITY AND CHANGE

1. What do you understand about climate variability and change?

………………………………………………………………………………………………………
………………………………………………………………………………………………………

2. How long have you known about climate variability and change?

0 – 3 years	4 – 7 years	9 years and above

3. How did you find out about climate variability and change?

………………………………………………………………………………………………………
………………………………………………………………………………………………………

4. Do you think you are currently experiencing climate variability and change?

Yes	No

4.1. If no, please elaborate on the reasons
………………………………………………………………………………………………………
………………………………………………………………………………………………………

4.2. If yes, please elaborate
………………………………………………………………………………………………………
………………………………………………………………………………………………………

5. What is the scale of impact of climate variability and change on maize production

High	Moderate	Slight	None

6. How has climate change affected your crops?

	Response	Code
Increased production		
Decreased production		
No change in production		
No production 4		
Other (specify)		

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SECTION C: PRODUCERS ADAPTATION MEASURES

1. Do you have access to agricultural extension support services

Yes	No

2. Have you adopted any adaptation measures?

Yes	No

3. If you done so, what adaptation measures are you using?

Adaptation measures	Response	Code
Supplemental irrigation		
Planning planting seasons based on the first rains		
Intercropping		
Production inputs		
Drought resistant crop varieties		
Crop rotation		
Other, specify		
No adaptations		

4. If you did not implement any adaptation measure, why?

……
……

5. What are the barriers to your implementation of adaptation measures to deal and cope with climate variability and climate change?

……
……

6. Do you receive any support from the provincial Department of Agriculture (extension services) regarding climate variability and change?

Yes	No

6.1. If yes, what kind of support do you receive?
……
……

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7. Are you aware of any departmental information dissemination programmes that deal with issues of climate variability and change?

Yes	No

7.1. If yes, please elaborate

………

………

8. Which language is used when information is disseminated?

………

………

9. How often do you attend training workshops for farmers?

	Response	code
Quarterly		1
Bi-annually		2
Annually		3
As it happens		4
Other (specify)		5

10. Are you involved in any other support forums?

Yes	No

10.1. If yes, please elaborate

………

………

11. What is the main source of water for crop production?

………

………

12. Do you have irrigation facilities?

Yes	No

13. Do you have any other information that you can add to what we have already discussed?

Yes	No

………

………

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APPENDIX B: GUIDING QUESTIONS FOR PROVINCIAL STAFF

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1. What do you understand by the term climate variability and change?
2. What are the indictors of climate change?
3. Where do you obtain information (and in what form) about expected effects of climate variability and change?
4. What crops do farmers grow in the Makhuduthamaga local Municipality area?
5. How long have you been aware of climate variability and change?
6. Which section of the local community is more affected by climate variability and change?
7. What challenges do farmers experience in relation to climate variability and change?
8. For how long have they been experiencing these challenges?
9. Do you think that farmers are aware of climate variability and change in their localities?
   9.1. If yes how did they acquired the awareness?
10. Are you aware of any policies and strategies to deal with climate variability and change at provincial office?
11. Should the farmers continue to experience these challenges, what activities are you planning to include in your programs to assist them have
12. Does government provide any help (subsidies) to farmers?
    12.1. If yes, in which form are these subsidies? (i.e. grants, fertilizers or seeds)
    12.2. If yes, at what percentage are the subsidies given?
13. What is the main source of water for crop production in Makhuduthamaga Local Municipality?
14. Do all farmers have irrigation facilities in this municipality?
    14.1. If no, what is the Department doing to assist those farmers access these?
15. Apart from climate climatic conditions, what other factors affect production (maize specifically) in Makhuduthamaga Local Municipality and what are their effects?
16. Which extension services does the Department provide to farmers?
17. Which language is used when disseminating information to farmers?
18. What is the minimum required qualification for employment as extension officer?
19. Does the Department support any climate variability and change research, monitoring and observation activities?
    19.1. If no, please elaborate on the reasons
    19.2. If yes, how does this activity influence the support provided to farmers?
20. What is the major obstacle to implementing the necessary measures to minimize the effects of climate variability and change in the Province?

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21. Do you have any other information that you want to add to what we have already discussed?

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APPENDIX C: GUIDING QUESTIONS FOR KEY INFORMANTS

1. What visible changes have you observed that are related to rainfall, temperature, crop productivity, flow of streams, occurrence of big floods, and incidence of drought in the farming area?
2. What is the occurrence level of drought in the locality? And what are the probable causes?
3. How is the trend of rainfall during the past 20 to 30 years? Is it increasing, decreasing, coming on time and stopping at the right time?
4. What coping and adaptation strategies have community adopted to alleviate problems arising as a result of climatic variability and change.
5. What effect has climate change had on the livelihood of the local farmers
6. What development interventions are carried out in the village to avert the impact of climate change?
7. How do you evaluate the sustainability of development interventions promoted by government and nongovernment?
8. Do you feel that farmers are happy to participate in development activities?
9. How do you evaluate the agricultural extension agents' role in motivating and mobilizing the community to strengthen their adaptive strategies to climatic changes?
10. What agricultural technology and climatic information system do you access regularly and during climatic extremes?
11. Do you receive warning information on short-term variations and/or long-term climate change from any sources?
12. Do you believe that it is possible to reduce or totally nullify the negative impacts of climate change?
    12.1. If yes how?
13. What are the successes stories that you observed in relation to coping and adaptation strategies adopted by farmers to withstand climate change?
14. What should the government and the community do to avert the impact of climate change in the municipality?

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APPENDIX D: RESPONDENT CONSENT FORM

RESEARCH ETHICS COMMITTEE

UNIVEN Informed Consent

Appendix D

LETTER OF INFORMATION

Title of the Research Study : The impact of climate change and variability on maize (*Zea Mays)* production in Makhuduthamaga Local Municipality, Limpopo Province, South Africa

Principal Investigator/s/ researcher : Selelo Wilson Matimolane, *BSc (honours*)

Co-Investigator/s/supervisor/s : Hector Chikoore, *PhD* & Edmore Kori, *M.EnvSc*

Brief Introduction and Purpose of the Study:

The purpose of the research study was to investigate maize producers' vulnerability to climate variability and change in the current context of expected change in climate. Due to problems of water shortages, droughts and climate variability, different reports (South Africa's Initial National Communication, 2000), have shown a decline in crop production in maize yields in South Africa. Maize is the most important grain crop in South Africa and is produced throughout the country under diverse environments. However, despite the crop being so important, its production is dependent on climatic conditions. This means that any change in climate can affect the production either negatively or positively. Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. The study will look to answer amongst others the following: how climate change affects maize production in the Nebo Maize Production hub, Limpopo Province of South Africa; to investigate the extent of maize producers' vulnerability to climate change and variability, as well as their associated farm level response/ adaptation.

Outline of the Procedures :

The study will adopt the distribution and administration of the questionnaires to the producers. These methods are explorative and descriptive in nature. A total of 100 questionnaires with closed and semi-structured questionnaires (attached ere as an appendix) were distributed to the producers during focus group sessions. Six focus group

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sessions will be conducted around Makhuduthamaga Local Municipality with respondents recruited from the different villages in the study area. Each focus group session will be made up of between 15 – 20 producers and will last approximately between three – five hours. A written informed consent detailing the aim of the study and the potential benefits to the participants will be sought prior to commencement. The participants will be assured that their privacy and confidentiality will be protected.

Risks or Discomfort to the Participant:

- Invasion of privacy (such as asking about education level or income).
- Breach of confidentiality.
- Loss on income.
- Illiteracy.

Benefits : The following are expected as outcomes of the study:

- Comparative rainfall and production trends in Makhuduthamaga Local Municipality;
- At least one journal article publication
- Critical knowledge to be used by producers on:
  - i. adaptation strategies adopted by famers and their success in coping with climate variability and change;
  - ii. how climate variability and change affects maize production in the Makhuduthamaga Local Municipality.
- The action plan for addressing the effects of climate change and variability on maize production in the area will be developed.

Reason/s why the Participant May Be Withdrawn from the Study:

A participant may be withdrawn from the study without any penalty for the following reasons:

- To maintain the integrity of the data (such as in cases when a participant is not following the study procedures).
- Illness.
- Inability to complete the survey (Boredom, mental fatigue, embarrassment at poor performance).

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- Personal reasons (advanced by the participants).

Remuneration : *None*

Costs of the Study : No, the researcher will cover the cost related to this study

Confidentiality : The opinions and identity of the respondents are viewed as strictly confidential, and only members of the research team will have access to the information. No data published in the resultant dissertation and journals will contain any information through which respondents may be identified. Anonymity is therefore ensured. Research participants/respondents may withdraw from the focus group at any time. Participation in the study is voluntary. Their attention is drawn to the fact that photographs of the interview process, cultivation area and of the plants will be taken for illustration purposes in the study. They will have access to the photographs should they wish to.

Research-related Injury : No *compensation* will be paid to participant's. The research only focusses on collecting information on the participant's perception of the impact and magnitude of climate variability and change on Maize Production in Makhuduthamaga Local Municipality. As such, no related injuries are expected to occur as a result on participation in this study. The discomfort nd risk that participants might encounter are covered in the relevant section

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher, Mr. Selelo Matimolane, Department of Geography and Geo-Information Sciences, School of Environmental Sciences, University of Venda. Tel: 076 924 0221, Email: Selelo1648@gmail.com

Please contact my supervisor, Dr. Hector Chikoore, Department of Geography and Geo-Information Sciences, School of Environmental Sciences, University of Venda. Tel: 015 962 8331, Email: hector.chikoore@univen.ac.za

The University Research Ethics Committee Secretariat on 015 962 9058. Complaints can be reported to the Director: Research and Innovation, Prof GE Ekosse on 015 962 8313 or Georges Ivo.Ekosse@univen.ac.za

General:

Potential participants must be assured that participation is voluntary and the approximate number of participants to be included should be disclosed. A copy of the information letter

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should be issued to participants. The information letter and consent form must be translated and provided in the primary spoken language of the research population

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, *Selelo Matimolane*, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ,
- I have also received, read and understood the above written information (*Participant Letter of Information*) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant	Date	Time	Signature
I, ………………………..……	**………………**		**…………………..**

I (Selelo Matimolane) herewith confirm that the above participant has been fully Informed about the nature, conduct and risks of the above study.

Full Name of Researcher

…………………… Date**…………..……..**Signature**…………………**

Full Name of Witness (If applicable)

……………………. Date **……………….**Signature**…………………..**

Full Name of Legal Guardian (If applicable)

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……………………..…Date………………..Signature…………………….

Please note the following:

Research details must be provided in a clear, simple and culturally appropriate manner and prospective participants should be helped to arrive at an informed decision by use of appropriate language (grade 10 level- use Flesch Reading Ease Scores on Microsoft Word), selecting of a non-threatening environment for interaction and the availability of peer counseling (Department of Health, 2004)

If the potential participant is unable to read/illiterate, then a right thumb print is required and an impartial witness, who is literate and knows the participant e.g. parent, sibling, friend, pastor, etc. should verify in writing, duly signed that informed verbal consent was obtained (Department of Health, 2004).

If anyone makes a mistake completing this document e.g. a wrong date or spelling mistake, a new document has to be completed. The incomplete original document has to be kept in the participant's file and not thrown away, and copies thereof must be issued to the participant.

References:

Department of Health: 2004. *Ethics in Health Research: Principles, Structures and Processes*

http://www.doh.gov.za/docs/factsheets/guidelines/ethnics/

Department of Health. 2006. *South African Good Clinical Practice Guidelines*. 2nd Ed. Available at:

http://www.nhrec.org.za/?page_id=14

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APPENDIX E: PRODUCERS ADOPTION OF ADAPTATION MEASURES

Appendix E-1: Adoption of supplemental irrigation by producers

Supplemental irrigation	Age of Producers				
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
Female	**2.63%**	**7.89%**	**18.42%**	**9.21%**	**38.16%**
No	0.00%	1.32%	3.95%	0.00%	5.26%
Yes	2.63%	6.58%	14.47%	9.21%	32.89%
Male	**3.95%**	**7.89%**	**31.58%**	**18.42%**	**61.84%**
No	0.00%	0.00%	2.63%	0.00%	2.63%
Yes	3.95%	7.89%	28.95%	18.42%	59.21%
Grand Total	**6.58%**	**15.79%**	**50.00%**	**27.63%**	**100.00%**

Appendix E-2: Adoption of Production inputs by producers

Production inputs	Age of Producers				
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
female	**2.63%**	**7.89%**	**18.42%**	**9.21%**	**38.16%**
No	0.00%	0.00%	3.95%	5.26%	9.21%
Yes	2.63%	7.89%	14.47%	3.95%	28.95%
male	**3.95%**	**7.89%**	**31.58%**	**18.42%**	**61.84%**
No	0.00%	1.32%	6.58%	2.63%	10.53%
Yes	3.95%	6.58%	25.00%	15.79%	51.32%
Grand Total	**6.58%**	**15.79%**	**50.00%**	**27.63%**	**100.00%**

Appendix E-3: Adoption of Intercropping by producers

Intercropping	Age of Producers				
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
female	**2.63%**	**7.89%**	**18.42%**	**9.21%**	**38.16%**
No	1.32%	1.32%	3.95%	2.63%	9.21%
Yes	1.32%	6.58%	14.47%	6.58%	28.95%
male	**3.95%**	**7.89%**	**31.58%**	**18.42%**	**61.84%**
No	2.63%	3.95%	6.58%	2.63%	15.79%
Yes	1.32%	3.95%	25.00%	15.79%	46.05%
Grand Total	**6.58%**	**15.79%**	**50.00%**	**27.63%**	**100.00%**

Appendix E-4: Adoption of drought resistant crop varieties by producers

Drought resistant crop varieties	Age of Producers				
Gender	**18 -**	**31 - 45**	**46 - 60**	**61 and above**	**Grand**

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	30				Total
female	**2.63%**	**7.89%**	**18.42%**	**9.21%**	**38.16%**
No	2.63%	2.63%	7.89%	2.63%	15.79%
Yes	0.00%	5.26%	10.53%	6.58%	22.37%
male	**3.95%**	**7.89%**	**31.58%**	**18.42%**	**61.84%**
No	0.00%	3.95%	15.79%	11.84%	31.58%
Yes	3.95%	3.95%	15.79%	6.58%	30.26%
Grand Total	**6.58%**	**15.79%**	**50.00%**	**27.63%**	**100.00%**

Appendix E-5: Adoption of planning planting seasons based on first rains by producers

Planning planting seasons based on the first rains			**Age of Producers**		
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
female	**2.6%**	**7.9%**	**18.4%**	**9.2%**	**38.2%**
no	1.3%	1.3%	5.3%	0.0%	7.9%
Yes	1.3%	6.6%	13.2%	9.2%	30.3%
male	**3.9%**	**7.9%**	**31.6%**	**18.4%**	**61.8%**
no	2.6%	3.9%	17.1%	9.2%	32.9%
Yes	1.3%	3.9%	14.5%	9.2%	28.9%
Grand Total	**6.58%**	**15.79%**	**50.00%**	**27.63%**	**100.00%**

Appendix E-6: Adoption of crop rotation by producers

Crop rotation			**Age of Producers**		
Gender	**18 - 30**	**31 - 45**	**46 - 60**	**61 and above**	**Grand Total**
female	**2.6%**	**7.9%**	**18.4%**	**9.2%**	**38.2%**
No	2.6%	2.6%	7.9%	3.9%	17.1%
Yes	0.0%	5.3%	10.5%	5.3%	21.1%
male	**3.9%**	**7.9%**	**31.6%**	**18.4%**	**61.8%**
No	0.0%	3.9%	18.4%	11.8%	34.2%
Yes	3.9%	3.9%	13.2%	6.6%	27.6%
Grand Total	**6.6%**	**15.8%**	**50.0%**	**27.6%**	**100.0%**

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