RESEARCH DISSERTATION

For the Degree

MSc ENVIRONMENTAL MANAGEMENT

in the

DEPARTMENT OF ENVIRONMENTAL SCIENCE
UNIVERSITY OF SOUTH AFRICA

TOPIC:

THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL CROP PRODUCTION IN THE VHEMBE DISTRICT MUNICIPALITY, LIMPOPO PROVINCE SOUTH AFRICA

By

MUSETHA MBONISENI AUBREY
STUDENT NO: 46344063

SUPERVISOR : Dr T.Demana

DATE : September 2016

CONTACTS
Email Address : tshenges@yahoo.com

DECLARATION

I hereby declare that the study titled **THE IMPACT OF CLIMATE CHANGE ON THE AGRICULTURAL CROP PRODUCTION IN THE VHEMBE DISTRICT MUNICIPALITY, LIMPOPO, 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 MSc in Environmental Management at the University of South Africa. The work has not been submitted before for any degree or examination at any other university.

……………………………. …2016/08/28………

SIGNATURE DATE

(Mr)Musetha M.A

ACKNOWLEDGEMENTS

I would like to thank the following people and institutions for their assistance and support for making this research possible:

Dr. T. Demana, for his supervision, guidance, encouragement and mentorship throughout the course of the study. I salute him for his time, patience and understanding. I also thank him for believing in me.

Dr. P. Maponya, for his co-supervision during the first quarter of the research and for accompanying me during the data collection to make sure that I collected the relevant data and correct procedures were followed.

Mrs Makhavhu, District Manager for the Vhembe Department of Agriculture for allowing me to do the research in her area. She provided valuable input and shared the departmental strategies with regard to crop production and management within the District.

Mr Mudzielwana and Mr Mukhanu (Agricultural Extension Officers) from the Vhembe Department of Agriculture. They allowed me to identify and engage with individual farmers in the area.

I would also like to thank communities from the Rambuda Scheme and Folovhodwe for allowing me to use their agricultural crops samples during the study.

I would also like to thank Dr. K. Zuma, for assisting with statistical analysis for all the data that were collected during site visits. Without your statistical skills and knowledge, this dissertation would not have been possible.

Finally, I also would like to acknowledge my employer, City of Johannesburg (Department of Environmental, Infrastructure and Services) for providing funds and allowing time to undertake this research.

ABSTRACT

The aim of this research was to identify the impacts and adaptation options of climate variability and change on agricultural crop production in Vhembe District Municipality. The study will contribute to the expansion of existing literature on climate change impacts on agricultural sector. The following two main objectives were formulated for the purpose of this study:

- To determine the level of awareness of small-scale maize farmers about climate change impacts and threats in Vhembe District Municipality (VDM),
- To compare the level of production scales between the farmers who are aware and the farmers who are not aware of climate change impacts and its threats.

The study area was the Vhembe District Municipality; a representative sample of 150 farmers (aged 18 – 65+ years, 46 percent males and 54 percent females) participated in the study. Vhembe District Municipality is one of poorest municipalities in Limpopo due to lack of infrastructure development, and as a result of that, there is an increase of socio-economic problems such as food prices increase, unemployment, scarcity of food, and lack of local markets. The study further covers the municipality's farming enterprises, systems, categories, infrastructure as well as other constraints that may be facing the emerging farmer in the District.

The study highlighted the lack of climate change information, reduction of livestock production and crop yields of the farmers in the Vhembe District. The literature studies show climate variability and change adaptation strategies such as planting different varieties, crop diversification, different planting dates and shortening of growing periods. This study draws on lessons learned, experiences, and other existing research on climate change impact and adaptation across the globe. It was concluded during the research that change in climate was already perceived by farmers in the Vhembe District and the study also presented perceived adaptation strategies used by farmers in the Vhembe District.

The study concludes that there is lack of local market, and low level of farmers' awareness about the impact of climate change on the crop production in the Vhembe district. This low level of awareness translates into a low level of crop production which results in increased socio-economic problems, low income, increased unemployment, increased crops diseases and reduced crop yields.

Keywords: Vhembe District Municipality, Crop and livestock productions, Climate variability, climate change, and agricultural production.

ABBREVIATIONS AND ACRONYMS

ADB:	Asian Development Bank
ADB:	African Development Bank
BFAP:	Bureau for Food and Agricultural Policy
CAADP:	Comprehensive African Agriculture Development Programme
CCSP:	Climate Change Science Program
CCSR:	Center for Climate Change Research
CEP:	Communicating Environment Programme
CGIAR:	Consultative Group on International Agricultural Research in Semi-Arid Region
CIFOR:	Center for International Forestry Research
COPA:	Committee of Professional Agricultural Organisations
CSAG:	Climate Systems Analysis Group
CSIRO-BOM:	Common Scientific and Industrial Research Organisation and Bureau of Meteorology
DAFF:	Department of Agriculture, Forestry and Fisheries
DBSA:	Development Bank of Southern Africa
DEA:	Department of Environmental Affairs
DEAT:	Department of Environmental Affairs and Tourism
DFID:	Department of International Development
DoE:	Department of Education
DWAF:	Department of Water Affairs and Forestry
GDP:	Gross Domestic Product
GGP:	Gross Geographic Product
GRSA:	Government Republic of South Africa
GSA:	Grain South Africa
IFAD:	International Fund for Agricultural Development
IFOAM:	International Federation of Organic Agriculture Movements
IFPRI:	International Food Policy Research Institute
ILO:	International Labor Organisation
IPCC:	Intergovernmental Panel on Climate Change
ISET:	International Symposium on Emerging Technologies
IUCN:	International Union for Conservation of Nature
IUFRO:	International Union of Forest Research Organisation

LDA:	Limpopo Department of Agriculture
LEDET:	Limpopo Department of Economic Development, Environmental and Tourism
LEGDP:	Limpopo Employment Growth and Development Plan
LIMDEV:	Limpopo Economic Development Enterprise
MERK:	Ministry of Environment, Republic of Korea
MG:	Mail and Guardian
MIG:	Montreal Implementation Group
NAFU:	National African Farmers Union
NAST:	National Academy of Science and Technology
NDA:	National Development Agency
NGO:	Non Governmental Organisation
NSWSG:	New South Wales State Government
OECD:	Organisation for Economic Co-Operation and Development
PACJA:	Pan African Climate Justice Alliance
PMSEIC:	Prime Minister Science, Engineering and Innovation Council
RDP:	Reconstruction and Development Programme
RSA:	Republic of South Africa
SADC:	Southern African Development Community
SAIRR:	South African Institute of Race Relations
SAWC:	Southern Africa Wildlife College
SAWS:	South African Weather Service
SAYB:	South Africa Year Book
StatsSA:	Statistics South Africa
TGA:	Tomato Growers Association
TIL:	Trade Investment Limpopo
UNDP:	United Nations Development Program
UNECA:	United Nations Environmental Climate Adaptation
UNESCAP:	United Nations Economic and Social Commission for Asia and Pacific
UNISDR:	United Nations International Strategy for Disaster Reduction
UNFCCC:	United Nations Framework Convention on Climate Change
USEPA:	United States Environmental Protection Agency
VDM:	Vhembe District Municipality
WMO:	Weather Meteorological Organisation

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Background

The United Nations Framework Convention on Climate Change (UNFCCC,2015) defines climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in in addition to natural climate variability observed over comparable time.

Climate change is a reality and it is the greatest environmental challenge that has an impact on the agricultural production in many ways. In general terms, agriculture production depends on climate conditions, such as temperature, evaporation and the amount of rainfall. The climate is a primary determinant of agricultural productivity and any significant changes in climate in the future will influence crop and livestock productivity, hydrologic balances, input supplies and other components of managing agricultural systems: (Adams *et al*., 1998).

Global climate change results in reduced food production, leading to higher food prices and making food less affordable for poor people. According to IPCC (2007), the global community is facing the impact of climate change now and into the future. The most affected livelihoods are in rural areas in developing countries, where poverty is widespread and agricultural productivity is low due to, amongst others, degrading natural resources, lack of markets and climate risks: (Vermeulen *et al*., 2010). Especially farmers and landless labourers who depend on their direct natural environment and rain fed agriculture for food security are exposed to the impacts of climate change. All of Africa is likely to warm during this century. The warming is likely to be larger than the global, annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics. The rainfall in southern Africa is likely to decrease in much of the winter rainfall region and on western margins. (IPCC, 2007).

A number of countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will likely reduce the length of the growing season as well as force large regions of marginal agriculture out of production. Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected. This would adversely affect food security in the continent. (IPCC, 2007). In the warm to hot tropics and subtropics, global warming holds few benefits for crop productivity. Even small temperature increases (less than 2°C) may reduce crops yields. Greater heat stress, particularly during sensitive flowering and early seed-development periods, will reduce yield significantly (Easterling *et al*., 2012).

According to Nhemachena *et al*. (2008), greater food and water stress due to climate change will worsen the vulnerability of the poor in three important ways:

- Increased insecurity of livelihoods, due to depleted access to natural resources that include fertile soil and water, but it will also affect other social, financial and physical assets.
- An increase of health risks as a lack of food and water will have serious implications for health.
- Constrained economic opportunities due to long and short term impacts of droughts and floods.

The Pocket Guide to South Africa 2012/13 from the Department of Agriculture, Forestry and Fisheries (DAFF), Indicated that the agricultural production remains the main source of livelihood for rural communities in South Africa; The primary agriculture contributes about 3% to South Africa's gross domestic product (GDP) and about 7% to formal employment. Producer prices of agricultural products have increased on average by 2,6% from 2010 to 2011. The weighted average price of field crops dropped by 7,4%. The gross income from field crops also decreased by 21,2%, from R40 306 million in 2008 to R31 768 million in 2011.

The National Agro-meteorological Committee (NAC) Advisory on the 08 DAFF 2011 Report indicates that from 2010, Limpopo received normal rainfall in average, except on areas around Vhembe, Mopani and Lephalale municipalities where below normal rainfall was experienced. Crops were in a poor condition due to high temperatures and insufficient rainfall during the critical stage of growth, especially for farmers who planted late. The average dam level was at 81% in 2011 as compared to 87% of 2010 during the same period. The rest of the dams across the province were at satisfactory levels with the exception of Middel-Letaba (5%); Nsami (34%) and Albasini (41%) dams.

The climate in the Limpopo Province ranges from tropical rainy along the coastal plain of Mozambique to tropical dry savannah and tropical dry desert further inland, south of Zimbabwe. Rainfall is highly seasonal and unevenly distributed spatially, with about 95 percent occurring between October and April, typically concentrated in a number of isolated rain days and in isolated locations. Rainfall also varies significantly from year to year (CPWF 2013). These rainfall characteristics limit crop production because annual rainfall mainly occurs during a short summer rain season with high interannual variations. Flooding and droughts are major Agricultural Production -mediated impacts of climate change in the Limpopo Province and it is known for its livestock farming in the northern drier parts, timber plantations in the southern area, The Kruger National Park in the east, and its fruit industry in the central zone, where Vhembe is located (CPWF 2013).

Vhembe is a prolific fresh agricultural crop production area, with large-scale exports testifying to the quality of production and the efficiency of many farmers. Vhembe produces no less than 4, 4% of South Africa's total agricultural output, including 8, 4% of the country's sub-tropical fruit and 6, 3% of its citrus: (Common Wealth Network South Africa, 2011). Climate conditions are subtropical with mild, moist winters and wet, warm summers. The annual rainfall per annum is about 500mm with over 80 per cent of the rainfall occurring between October and December. The average annual potential evaporation in the Vhembe area is higher than the rainfall in almost all other districts in the Province. However, the rates differ from place to place depending on the topography. One of the areas with the highest rate of evaporation is around Musina. The annual rate of evaporation in Musina exceeds 2,700 mm.

Agricultural production is expected to be the most affected by these changes because it is highly dependent on climate variables such as temperature, evaporation and precipitation (IPCC, 2007). Climate change, by adversely affecting water resources, will threaten progress and efforts made in accelerating agricultural crop production in the VDM. Although the Agricultural sector is the main driver of the local economy in the VDM, unemployment rates are high in the District, most rural households depending on social grants and on their direct natural environment for the collection of fruits, fodder, vegetables, medicinal plants, firewood and water (Bouma *et al*., 2011).

1.2. Problem statement

Climate Change and associated changing rainfall patterns, rainfall reduction, and increasing dry spells and drought will reduce soil moisture (Thornton *et al*, 2009). This, along with rising temperatures and increased evapo-transpiration, crop water deficits at critical times in crop development can result in declining yields. Where the most crops are not irrigated, food production will drop (One World, 2010).

Higher temperatures will result in greater evaporative losses from dams as well as from the ground surface (Fauchereau *et al.*, 2013). With higher temperatures more irrigation will be required for agriculture and more water will be needed for cooling of industrial equipment and processes. The latest climate change projections indicate that both temperature and evapo-transpiration (increases in evaporation) are likely to increase the incidence of drought potential even if total rainfall of an area increases into the 21st century (Van Jaarsveld Chown, 2001).

The agricultural production and water resources are the biggest contribution to the local economic development in the VDM but as a result of climate change the agricultural production is decreasing (VDM IDP Report, 2013/2014).

There has been a noted decline in seasonal rainfall, as well as an increase in temperatures, conditions not favourable to agricultural crop production in the VDM which results in low production of the farmers and increase to the incidence of household food insecurity (Nesamvuni, 2011).

However, in light of these debates, the aim of the study was to provide answers to the questions: How do small-scale farmers become aware about climate change? Is adaptation the key to dealing with the impacts of climate change? Is the state proactive in building capacity of farmers to adapt to climate change? Answers to such questions are critical towards taking steps to reduce the vulnerability of small-scale farmers to the effects of climate change. Having identified the research problem, the next section will present the objective of the study.

1.3 Research objectives

The overall objective is to create awareness through which farmers can understand the meaning of climate change and its possible impacts on maize production in the VDM.

Specific objectives are to:

(a) Determine the level of awareness of small- scale maize farmers about climate change impacts and threats in Vhembe District Municipality (VDM).

(b) Compare the level of production scale between the farmers who are aware and the farmers who are not aware of climate change impacts and its threats.

(c) Find out the factors which influence the level of farmers' awareness to climate change impacts and its threats.

1.4 Significance of the study

According to IPCC (2007), climate change is one of the greatest challenges facing humanity and is expected to impact on agricultural crop production in many ways. Optimal crop-growing zones will migrate. Crop pest habitats will shift, as will diseases. Higher carbon dioxide levels and changing precipitation patterns will change crop yields. The impact of climate change has a negative impact on agricultural crop yields and thus it is important to understand and asses them in order to provide adaptation strategies. The impact of climate change on crop productivity requires a three pronged strategy: anticipation of change, adaptation and mitigation:

- Anticipation of change will require developing information systems, modelling and improving human resources to understand climate change and its possible impacts.
- Adaptation to climate change involves adjustments to planting time and cropping patterns; development of new varieties that are tolerant to drought, floods, disease and soil acidity and salinity; development and use of new technology; and more efficient water use.
- Mitigation of climate change will require improved farm management, including soil nutrition management, land use planning, agroforestry development, feed, waste and manure management. Benefits from better farm management include greater carbon sequestration and improved water management (Weinberger Basuno, 2011).

This research will assist the Vhembe District to select the necessary adaptation strategies in order to increase their productivity and help the agricultural sector in the district to adapt to the adverse consequences of changing climatic conditions. It will also draw on the findings of a significant amount of research that has already taken place in the area with an aim to engage stakeholders in the development of an information system focused on climate change adaptation

1.5 Limitations of the study

The findings of this study are not generalised to the whole Limpopo Province but seek to contribute to the discourse of climate change adaptation and the level of understanding for the impact of agricultural crop production by the climate change on Vhembe District farmers. The study focused on the key variables, which are climate change adaptation and household food security.

The research was limited in some aspects for particular reasons. The questionnaires used for data collection were prepared in English and most of the farmers were illiterate. Therefore, translation of the questions to their own languages was needed in order to complete the filling in of the questionnaires. Also, some farmers could not really provide accurate answers in filling in the questions especially on the observation of climate change as they did not record or document the climate trends over the years.

1.6 Summary

This chapter provides the background on the issue of climate change as an important environmental issue facing the nation at large today. It is assumed that majority of farmers in the Vhembe District are using different coping and adaptation strategies in order to increase their crop yields, for example crop diversification, planting early matured maize varieties, etc. In the chapter several literature studies show that climate change adaptation strategies vary from area to area due to agro-ecological zones and the harshness of the effects of climate variability and change.

The next chapter describes and focuses on the theoretical and empirical studies relating to climate change adaptation. The next chapter will also outlined the threats, impacts that climate change poses across key strategic climate – sensitive sectors across the globe.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

According to IPCC (2011), the scientific community widely agreed that climate change is already a reality. This chapter reflects on concepts and understanding of climate change being an average pattern of weather over a long term. It also highlights the causes and the consequences of climate change. Climate change has been perceived in terms of extreme heat and floods, droughts and heavy rains, declining rainfall patterns, and rise in sea level. All these factors have a great impact on agriculture. The impacts are negative, and it could be seen on food and agriculture, health, water resources, ecosystems, shelter, vulnerable populations and national security. The chapter further explains the future climate change in the study area and the level of awareness in many countries in Africa.

There is no doubt that the climate is increasing warmer currently; indications of that change are evident around us. According to IPCC (2012), the scientific community widely agreed that climate change is already a reality. The study of climate change cuts across many fields, which include geology, meteorology, and even oceanography. Over the past century, surface temperatures have risen, and associated impacts on physical and biological systems are increasingly being observed (IPCC, 2012). Climate change will bring about gradual shifts such as sea level rise, movement of climatic zones due to increased temperatures,
and changes in precipitation patterns (Wang *et al.,* 2011).

In addition, as agreed by the majority of scientists, climate change is mainly driven by the emission of greenhouse gases, such as carbon dioxide, methane and nitrous oxide (IPCC, 2012).Among other sources of emissions, agriculture is one of the most important contributors. Agriculture is one of the most important sources of emissions of greenhouse gases and the sector is increasingly being recognized for its potential to be part of the solution (IPCC, 2007). According to Smith (2008), energy and chemical intensive farming led to increased levels of greenhouse gas emissions, primarily as a result of the over-use of fertilizers, land clearance, soil degradation, and intensive animal farming (Smith,2008) .

There is evidence that the climate has changed and is continuing to change. Three of the resulting changes of the climate are changes in precipitation, temperature and extreme events such as droughts and floods. The impact of climate change is felt by farmers mainly in the "timing, frequency and intensity of rainfall events, and in the distribution of these events within a season of growth" (Blignaut *et al*, 2009). Annual average temperature and precipitation are important in assessing climate changes but do not provide adequate indication of the impact these changes have on individual farmers.

Climate is a primary determinant of agricultural productivity and as such, it influences the types of vegetation that can grow in a given location (Box, 1981; Woodward, 1987). In this context, agriculture is a complex sector involving different driving parameters (such as physical, environmental, economic and social). It is now well recognized that crop production is very sensitive to climate change (McCarthy et al., 2001), with different effects according to region.

Crop production for four major crops (maize, soybean, wheat and rice) is located in a small number of major producing countries, with a large amount of overlap across the crops. This means that the exposure of a large proportion of global production of the major crops is concentrated in particular parts of the globe, and so extreme weather events in these regions have the largest impact on global food production (Challinor *et al.*, 2015)

2.2. Impact of climate change in different sectors across the world

According to the United Nations (2015), there are still 836 million people in the world living in extreme poverty (less than USD1.25/day). And according to the International Fund for Agricultural Development (IFAD), at least 70 percent of the very poor live in rural areas, most of them depending partly or completely on agriculture for their livelihoods. It is estimated that 500 million smallholder farms in the developing world are supporting almost 2 billion people, and in Asia and sub-Saharan Africa these small farms produce about 80 percent of the food consumed (IFAD, 2011).

The world's climate is continuing to change at rates that are projected to be unprecedented in recent human history. According to IPCC (2012), most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

Globally, climate change is being observed in different perspectives. The International Fund for Agricultural Development (IFA, 2010) reported that Asia is the most populous continent in the world. In Asia, past and present climate trends and variability have been characterized by an increasing temperature, which is more pronounced during winters (IPCC, 2007). In the Asia/Pacific region there is evidence of prominent increases in the intensity and/or frequency of many extreme events such as heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, snow avalanches, thunderstorms, and severe dust storms in the region (Cruz *et al.,* 2007). According to IFAD (2009), climate change poses a serious and additional threat to poor farmers and rural communities in the region who live in remote and marginal areas such as mountains, dry lands and deserts. Threat is also posed in areas with limited natural resources, communication and transportation networks and weak institutions. Climate models indicate temperature increases in the Asia/Pacific region on the order of 0.5-2°C by 2030 and 1-7°C by 2070. Temperatures are expected to increase more rapidly in the arid areas of northern Pakistan and India and western China (IFAD 2009).

According to Hall (2009), climate change impacts will be overwhelmingly severe for Asia. Asia's rapidly growing population is already home to more than half of humanity and a large portion of the world's poorest people. Climate change had started threatening development in the region and could continue to put livestock production and food security at risk by the 2020s (Hall, 2009).

The Intergovernmental Panel on Climate Change (IPCC, 2013) state that the average surface temperature of the earth has increased during the twentieth century by about 0.6° ± 0.2°C. (The ± 0.2°C means that the increase might be as small as 0.4°C or as great as 0.8°C). IPCC (2011) further reported that it is warmer today around the world than at any time during the past 1000 years. Extreme weather events are now on the rise worldwide and are more likely to happen in the future (Easterling *et al.,* 2012). Climate in terms of extreme temperature is increasing from time to time. The majority of the world's poor and food-insecure people are rural, with direct or indirect dependence on agricultural production and income for their livelihoods, and are thus directly exposed to any risk that would impact agricultural production.

In North America, Mexico is vulnerable to climate change. Mexico, like many developing countries, has a potential to be vulnerable to economic damages caused by global climate change (Thornton *et al*, 2009). Furthermore, the presence of large-scale poverty and a highly skewed income distribution exacerbates the situation and increases the vulnerability of certain areas to weather related issues. According to Liverman and O'Brien (1991), Mexico is particularly prone to suffer at least two different types of these events such as droughts and hurricanes. The reason is not far from the fact that Mexico is a developing country and most developing countries majorly based their economic activities on agriculture. According to the Hazard Management Unit of World Bank (2004), a study indicated that Mexico is ranked 32 among the 60 countries affected by potential hazards such as floods, and droughts and Mexico is predicted to be likely to face repeated disaster repeated losses.

In Europe, Anderson and Bausch (2006) explained a link between climate change and weather disasters. The magnitude of the rise in mean temperatures and the existence of severe extremes were inconsistent with the natural cycles. They were consistent with influence on human induced greenhouse gases. More examples were intense precipitation and increased droughts and hurricanes. All these happen in many European countries as a result of climate change.

Below are briefly highlighted a number of key sectors that are vulnerable to the climate change.

2.2.1. Climate change impacts on agriculture and food based on international perspective

Agriculture is an economic activity that is highly dependent upon weather and climate in order to produce the food and fibre necessary to sustain human life. Not surprisingly, agriculture is deemed to be an economic activity that is expected to be vulnerable to climate variability and change. The vulnerability of agriculture to climate variability and change is an issue of major importance to the international scientific community, (UNFCCC, 2012). On a global basis, climate variability and change may have an overall negligible effect on total food production (Parry Rosenwieg, 2011); however, the regional impacts are likely to be substantial and variable, with some regions benefiting from an altered climate and other regions adversely affected. Generally, crop production is likely to decline in most critical regions (e.g. subtropical and tropical areas).

The observed effects of past climate trends on crop production are evident in several regions of the world (Porter *et al.,* 2014), with negative impacts more common than positive ones, including several periods of price spikes following climate extremes in key producing regions. There is evidence that climate change has already negatively affected wheat and maize yields in many regions and also at global level (Lobell, Schlenker and Costa-Roberts, 2011).Among the major crops, wheat is relatively widely distributed, while maize and soybean are especially concentrated in a small number of countries. Almost two thirds of the soybeans produced globally come from either the US or Brazil (and including nearby Argentina the production fraction is more than 80%)

Agriculture in the United States produces approximately $300 billion a year in commodities with livestock accounting for roughly half the value global agricultural crop production (L.Wright-Morton L.H.Ziska, 2012, Hope 2009:455).

Production of these commodities is vulnerable to climate change through the direct (i.e. abiotic) effects of changing climate conditions on crop and livestock development and yield (e.g. changes in temperature or precipitation), as well as through the indirect (i.e. biotic) effects arising from changes in the severity of pest pressures, availability of pollination services, and performance of other ecosystem services that affect agricultural productivity. Climate change poses unprecedented challenges to U.S. agriculture because of the sensitivity of agricultural productivity and costs to changing climate conditions. Adaptive action offers the potential to manage the effects of climate change by altering patterns of agricultural activity to capitalize on emerging opportunities while minimizing the costs associated with negative effects. The aggregate effects of climate change will ultimately depend on a complex web of adaptive responses to local climate stressors. These adaptive responses may range from farmers adjusting planting patterns and soil management practices in response to more variable weather patterns, to seed producers investing in the development of drought-tolerant varieties, to increased demand for Federal risk management programmes, to adjustments in international trade as nations respond to food security concerns.

The Canadian Agriculture crop production contributes 2.5 percent (Wheaton Canadian Climate Programme Board, 2011) although grain production has historically been associated with Prairie agriculture and continues to account for the majority of production, in recent years many farmers have begun to diversify into specialty crops (e.g. mustard seed, dry peas and lentils). In some areas of extreme moisture deficits, extensive irrigation systems have also been developed. For example, almost 500,000 ha of farmland is currently under irrigation in southern Alberta, producing a wide variety of crops including grains, pulse crops, corn, sugar beets and vegetables. The raising of livestock is also an important agricultural activity, particularly in terms of cattle. More than 50% of Canada's beef cattle are now raised in western Canada, and much of this is concentrated in Alberta. Livestock operations across the prairies are also diversifying with the introduction of buffalo, emus, and elk. Some farmers have recognized that the indigenous species, such as the buffalo and elk are more accustom to the climate of the prairies, than traditional livestock, and might reduce some of the climate stress.

2.2.2. Climate change impacts on agriculture and food based on continental perspective

Currently, about 48% of Africa's population or approximately 450 million people live in extreme poverty, on less than US$1.25 per day, with 63% of the continent's poor living in rural areas depending on agriculture for their livelihoods (World Bank, 2015). At the same time, the continent is experiencing rapid increase in population and urbanization. Half of the 2.4 billion increase in global population that will occur between 2013 and 2050 will occur in sub-Saharan Africa (SSA), and 56% of Africa's population is projected to live in urban areas by 2025 (UNDESA, 2013 and 2014).

In its Declaration on Climate Change and Development in Africa adopted in January 2007, member states of the AU acknowledged African's vulnerability to climate change and that 'climate change could endanger the future well being of the population, ecosystems and socioeconomic progress of Africa'. A few months later, in April 2007, the IPCC concluded that Africa is one of the continent's most vulnerable to climate variability and change owing to 'multiple stresses and low adaptive capacity', and despite the fact that some adaptation is taking place 'this may be insufficient for future changes in climate'. Africa's vulnerability arises from a combination of many factors, including extreme poverty, a high rate of population increase, frequent natural disasters such as droughts and floods, and agricultural systems (both crop and livestock production) that depend heavily on rainfall.

Maize, sorghum and millet occupy the highest crop areas for all of Africa, but with considerable variation across regions. An International Food Policy Research Institute (IFPRI) climate change impact study on crop yields in Africa (Thomas and Rosegrant, 2015) shows significant geographical variation of impacts, indicating that, while most direct climate change impacts will be negative, there will be positive impacts on yields in some areas with projected increases in precipitation, and in some elevated areas that will be able to be cultivated due to warmer temperatures.

The agriculture sector in African countries has been worst affected by climate change. Hope (2009:455) indicated that 'majority of the African population derive their livelihood from agriculture which is the largest economic activity in the continent'. Hope (2009:456) further observed that in Africa small scale agriculture that is practised by many farmers 'relies heavily on rainfall for the provision of water for crops' and climate change creates havoc for African farmers. The farmers in Africa can be classified in two broad categories. There are the large commercials farms, which occupy the best soils and intensively use technologies such as improved seeds, fertilisers and mechanisation. Maize yields of more than 5 tonnes per hectare are common in these conditions. However, the overwhelming majority of farmers in Africa have small land holdings and use rudimentary methods for crop production.

According to Boko *et al,* (2007), Agriculture and natural resources provide the livelihood for 70% to 80% of the population, and account for 30% of GDP and 40% of export revenue in Sub-Saharan Africa. The agriculture employs 60% to 90% of the total labour force (Thornton *et al,* 2006). Since these farmers depend almost entirely on agriculture for employment and income, they often cannot find the money needed to purchase food even if it is available in the market. In recent years, food importations by both governments and the private sector have significantly increased. Changes in climate could have significant impacts on food production on the continent of Africa.

In aggregate, African agriculture will be worse off with climate change. Even though warming expands supply and reduces agricultural prices, the prices will be harmful to farmers in Africa (World Bank, 2012). Areas that are currently marginal could find themselves unsuitable for agriculture in the future. Under a business as usual scenario, a 2^{O}C increase could, by the 2050s, result in 12 million people at risk from hunger as a result of falling crop yields. Increases in temperature to 3.3^{O}C and 3.4^{O}C could result in about 60 million and 70 million people respectively at risk. Even though increases in temperature increase livestock revenues for small farmers, the overall effect is losses in billions of dollars from livestock revenues since large farmers dominate the sector. One explanation for this is that farmers shift into crops as rainfall increases, given rainfall increases crop productivity. Second, increased precipitation reduces the quality of grazing for animals as grassland become forests. Third, is an increase in animal diseases thereby reducing the population of livestock.

Ethiopia is one of the least developed countries in the world with a gross national income (GNI) of US$22.7 billion and a population of more than 80 million (World Bank, 2012). Agriculture is the source of livelihood to an overwhelming majority of the Ethiopian population and is the basis of the national economy, where small-scale subsistence farming is predominant. This sector employs more than 80% of the labour force and accounts for 45% of the GDP and 85% of the export revenue (Ministry of Finance and Economic Development 2012). Ethiopian agriculture is heavily dependent on natural rainfall, with irrigation agriculture accounting for less than 1% of the country's total cultivated land. Thus, the amount and temporal distribution of rainfall and other climatic factors during the growing season are critical to crop yields and can induce food shortages and famine.

In Kenya, agriculture as an income-generating sector contributed 21.4% and 24% of the country's GDP in 2010 and 2011 respectively (KPMG Kenya, 2012). In addition, smallholder farmers provide 75% of the labour force and 75% of the market output produce (Alila & Atieno 2006). Climatic instability negatively affects agricultural productivity leading to substitution through importation or a shift to other sectors. These effects have a direct impact on smallholder farmers. This is because smallholder farmers, the main contributors of domestic food, mostly rely solely on rain-fed agriculture and have a limited means of coping with this adverse weather variability(FAO, 2012). Productivity variation attributed to these continual climatic changes is also known to cause changes in agricultural production trends. In 2009, over 3.5 million Kenyans faced severe food shortages as a result of failed rainfall seasons, which led to intense drought (Asiti, 2010).Despite the uncertainties, the smallholder farming community plays a huge role in addressing world poverty and eradication (FAO *et al*, 2012). This is through combating the effects of climate change and variability by adoption new approaches to their agricultural systems. Unfortunately, awareness about climate change in developing countries is still rather low compared to the developed world, with African countries rated as the least aware (Pelham, 2009).

Boko *et al., (*2007) further indicated that agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability. A number of countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will be likely to reduce the length of growing season as well as force large regions of marginal agriculture out of production (IPCC, 2007). Projected reductions in yield in some countries could be as much as 50 percent by

2020, and crop net revenues could fall by as much as 90 percent by 2100, with small-scale farmers being the most affected. This could adversely affect food security on the African continent.

The crop model indicates that in 2050 in most parts of Africa, average rice, wheat and maize yields will decline by up 20 percent, 25 percent and 30 percent respectively (IFPRI, 2009). This matter is further supported by Kalaugher (2010) when she said climate change will reduce production of five staple crops in Africa – maize, sorghum, millet, groundnut and cassava – by a mean of between 8 and 22 percent. In all cases except cassava there is a 5 percent chance that yields could drop by more than 27 percent.

2.2.3. Climate change impacts on agriculture and food based on national and provincial perspective

On the 17th of October 2014, President Jacob Zuma emphasized the important of active citizenship in fight against climate change for food security to ensure human development in the developing countries and rural areas (UNCCC, 2014).
According to Long-Term Adaptation Scenarios, Flagship Research Programme (LTAS, 2013) .The South African agricultural sector is highly diverse in terms of its activities and socio-economic context. Only 14% of the country is currently considered potentially arable, with only one fifth of this land having high agricultural potential. Overall, many agricultural sub-sectors are sensitive to projected climate change. Certain crops grown in South Africa are more tolerate to extreme climate event, climate variability and also heat tolerant, for example groundnuts, sorghum etc, change, while others are more heat sensitive ,for example ,maize, tomatoes etc. Similarly, climate change impacts for some crops can be projected with more confidence than for others (DEA, 2011). The smallholder and subsistence dry land farmers are more vulnerable to climate change than commercial farmers, while large-scale irrigated production is probably least vulnerable to climate change, conditional upon sufficient water supply for irrigation being available (Schulze, 2010; DAFF, 2013).

In South Africa, the agricultural sector plays a significant role in the country's economy. Anecdotal evidence suggests that climate change could lead to a fall of about 1.5% in the country's GDP by 2050 – a fall roughly equivalent to the total annual foreign direct investment in South Africa at present. In addition, climate change has severe consequences on other economic sectors that are either directly or indirectly linked to the agricultural sector (DEA, 2011). Today, South Africa is not only self-sufficient in virtually all major agricultural products, but is also a net food exporter. Farming remains vitally important to the economy and the development of the southern African region. However, South African farming is also vulnerable to the variations in weather patterns associated with changes in global temperatures (Anderson *et al*., 2007).

In the agriculture of South Africa, the types of crops, cropping calendars and production levels are very diverse, owing to the influence of the different agro-climatic zones, from the dry north-western region to the wet eastern region. The major crops are maize, wheat, sugar cane, sorghum and the minor ones are groundnuts, sunflowers, dry beans, tobacco and potatoes. Fruit of importance includes apples, grapes, pears, peaches and dried fruits. In addition, the numbers of livestock on the country's commercial farms were estimated at 13.5 million head of cattle, 29 million sheep and 6.6 million goats (DEA, 2011).

As South Africa's staple food crop, maize has been under the spotlight since the late 1990s, in regard to vulnerability research (Du Toit et al. 2002) and to productivity (Schulze *et al*., 1995), as well as subsequently from a sustainability perspective (Walker and Schulze, 2006; 2008). Yields have been simulated to be sensitive to both climate and CO2 fertilisation, with doubled CO2 offsetting much of the reduced profitability associated with a 2 °C temperature rise, especially in core areas of maize production (Walker and Schulze, 2008). There is a remarkable correlation between rainfall and crop production, whether summer (e.g. maize) or winter crop (e.g. wheat), winter rainfall (April–September) from summer rainfall (October–March).

Dry spells occur naturally during the growing season in winter, and the projected decrease in winter rainfall would potentially accentuate this natural effect. In cases where areas are already close to threshold values for maximum temperature, a further temperature increase can have devastating effects on production potential (ERC, 2007). A study by Schulze and Davis (2012) using the Smith (2006) wheat yield model shows winter wheat yields to increase slightly by 0.5 to 1.5 t/ha /season into the intermediate future in the main wheat growing Swartland and Rúens regions of the Western Cape, with similar increases in the Eastern Free State wheat belt, while into the more distant future most of the Western Cape's wheat belt is projected to show decreased yields of 0.5 -1.0 t/ha from the present, but with the Free State continuing to display increases.

Sorghum (Sorghum bicolour) is a relatively drought resistant crop which can tolerate erratic rainfall. Areas for sorghum suitable under present climatic conditions are projected to become unsuitable by the intermediate future along the eastern border while considerable new areas, presently climatically unsuitable for sorghum, are projected to be gained in the Free State and Eastern Cape (Schulze, 2011). Sorghum yields are projected to potentially increase by 2 -4 t/ha into the intermediate future in parts of western KwaZulu -Natal, the Eastern Cape inland and eastern Free State, with some areas in the north registering losses compared with present climatic conditions. This translates to projected increases in excess of 30 % in the central growing areas, with some yield decreases along the eastern periphery.

For soybeans the areas lost to potential production in both the intermediate and more distant future are in the east, with an expansion of climatically suitable areas inland towards the west into the future, and with areas gained and lost being more sensitive to changes in rainfall than increases in temperatures (Schulze, 2011). Projected changes of soybean yields between the intermediate future and present climate scenarios display an arc of yield decreases for the climatically suitable growth areas surrounding a considerably larger core area of median yield increases (generally by > 30 %). By the more distant future both the areas showing decreases and increases have become amplified. The implication is that while major expansion of climatically suitable areas for soybean production might occur, there is also likelihood that the area of actual production may become more concentrated.

The western part of the country is seen becoming much drier while the east is afflicted with increasingly severe storms. According to Musvoto (2009), as its western regions dry out, South Africa would have to turn to more drought-resistant strains of maize, or corn, and rely more on the role of genetically modified strains. The uncharacteristically high rainfall during January and February 2011 resulted in significant losses to both wine and dry grapes in the Northern Cape (Modiba, 2011). This effect of lower wine and dry grape production will result in R300 million losses to farmers in the province. Maize in the Northern Cape is also predicted to fall from 635000 tons from the previous season to 575000 tons in 2011 (Modiba, 2011). This is mainly due to the effects of the floods.

2.2.4 .Climate change impacts on agriculture and food based on Limpopo and Vhembe District Municipality (VDM) perspective

Limpopo Province is one of South Africa's richest agricultural areas. It is a major producer of vegetables. The subtropical climate enjoyed by much of the province gives rise to the cultivation of tea, coffee and fruits, especially tropical fruits. Forestry makes a major contribution to the economy, as do tobacco, sunflower, wheat, cotton, maize, and groundnuts. Livestock farming includes cattle ranching and game. The abundance of orchards with various sub-tropical fruits and nuts form the basis of a thriving agro-industrial sector (StatsSA, 2014)

Limpopo is the breadbasket and agricultural engine of South Africa, accounting for nearly 60% of all fruit, vegetables, maize, wheat, and cotton. Livestock farming is also a significant contributor to the province's agriculture sector. It is the source of 65% of the country's papayas, 36% of its tea, 25% of its citrus fruit, bananas, and litchis, 60% of its avocados, 60% of its tomatoes (40% by one company alone), and 35% of its oranges. It produces 285,000 tons of potatoes annually. An estimated 33% of households in Limpopo are considered agricultural households, and the province is home to 16% of South Africa's agricultural households. Despite this, the agriculture sector contributed only three percent to the province's annual average Gross Domestic Product (GDP) in 2012.

The varied climates allow Limpopo to produce a wide variety of agricultural produce
(Oni SA *et al.*, 2013). Sunflowers, cotton, maize and peanuts are cultivated in the Bela-Bela and Modimolle areas. Modimolle is also known for its table-grape crops. Tropical fruit, such as bananas, litchis, pineapples, mangoes and papaws, as well as a variety of nuts, are grown in the Tzaneen and Makhado areas. In addition to
several thousand tonnes of potatoes, Limpopo produces the majority of South Africa's mangoes, papayas, avocados, citrus and tomatoes in the VDM.

Limpopo province is particular vulnerable to climate variability and change as agricultural production depends on climatic conditions and largely on the quality of the rainy season. According to Letsatsi – Duba (2009) climate change in Limpopo province is taking place in the context of other developmental stresses, notably poverty, unemployment and food insecurity which it is feared that it will exceed the limits of adaptation in other parts of the province.

According to DAFF (2011), climate change in the Limpopo Province is raising temperatures, reducing rain and its timing. This in turn is putting pressure on the province's scarce resources, with implications for agriculture production. It is thus important to enable adaptation in the livestock sector particularly in the Limpopo Province where the livestock sector is a critical component of the formal and informal economy. Farmers in the Limpopo Province are thus facing a possible negative impact on crop yields, especially farmers without advanced technology and good modern agricultural practices (Tshiala Olwolch, 2010). As a consequence, less food is directly available to the household.

The Limpopo Province is the main tomato growing area in South Africa, producing 66 percent of the total annual tonnage of tomatoes (DAFF, 2010). According to Tshiala and Olwoch (2010), there is an increase of tomato production in Limpopo
for certain years and there are some decreases of production in a certain period because of the sensitivity of the tomato crop to climate variability and change.

VDM is one of the high-potential agricultural areas of the province. Farmers in this district (including Tshakhuma, Mutale, and Rabali and Tshiombo areas) produce subtropical and tropical crops (Mahapa et al., 2001). In this district, agriculture is one of the key livelihood activities. In the Tshakhuma area, for example, 70% of the farmers in the area planted perennial crops such as avocado, followed by banana producers (18%) and "others", including groundnuts, maize and cowpea. Avocado and banana crops are usually grown in the Tshakhuma area favoured by good climatic and soil conditions. The other reason for having a number of banana producers is because Levubu farmers, who are farming on the eastern side of Makhado, used to collaborate with Tshakhuma farmers. This helped Tshakhuma farmers to access banana seedlings easily. Less than eight percent of the farmers in the Tshakhuma area produce cabbages, and another four percent of the farmers produce seasonal crops such as onion, carrots, lettuce and cabbage.

The average annual rainfall in the VDM is 820 mm (ARC-ISCW, 2014). The rainy season starts in October in most areas of the Limpopo Province especially in the VDM. The rainfall pattern peaks in January-February months, and thus when floods are also expected. Rainfall exceeds the potential evapotranspiration in months (December to March). It was also noted that the meteorological drought is the result of the negative deviation of rainfall from the mean and is normally the most common indicator for drought (Wilhite *et al.*, 2000).

VDM sometimes experiences extremes in temperatures. When the temperature is high, there is also a high probability of evaporation during that particular period. Temperatures, for example, can reach more than 35^{o}C during summer. According to Mpandeli, 2006, the average monthly maximum temperature most of the time can reach more than 35^{o}C especially during summer (Mpandeli, 2006).

VDM have always apply different coping and climate change adaptation strategies in order to increase production during drought periods including: (a) Adjust fertilizer inputs, (b) Practice crop diversification, (c) Food preservation (d) Adopt destocking during uncertainty periods.

2.3. Impact of climate change on economic and social consequences

Food security vulnerabilities to climate change encompass the environmental (productive), economic and social dimensions. IPCC (2014a) has further described situations of institutional vulnerability, pointing to the key role of governance to condition vulnerabilities. Impacts on production directly translate in economic impacts at various scales, on the farm and in the food chain, and with social consequences, Lam *et al.* (2012). The effects of climate change are translated into social and economic consequences through a range of different pathways that can result in changes in agricultural incomes, food markets, prices and trade patterns, and investment patterns. At farm level, they can reduce incomes. They can impact physical capital. They can force farmers to sell productive capital, for instance cattle, to absorb income shocks. They can reduce the capacity to invest (Eriksen *et al.*, 2011). This directly bears social impacts on farming households, limiting their capacity to face other expenditures, such as health and education.

At national level, they can trigger an increase in agricultural commodities' prices (food and feed), which impact the economic and social status of the whole population, particularly in countries where an important part of the household budget is spent on food (Caldzilla *et al.,* 2013). This triggers macro-economic effects for agriculture-dependent countries for which agriculture is an important part of GDP, and/or for which agriculture constitutes an important part of employment. Climatic risks can also hinder agricultural development by discouraging investments (Bárcena *et al.,* 2014), Climatic shocks that impact a significant volume of worldwide production or an area of importance in terms of world markets have global consequences on markets: (i) quantity and price effects, with increased tension on markets; and (ii) impacts on bilateral contracts and/or import/export behaviour, with disruption of trade patterns.

Given the high level of dependency of poor and food-insecure people on agriculture for their incomes including rural labourers as well as family farmers and smallholder producers the potential impacts of climate change on agricultural incomes is of considerable concern. Likewise, the potential negative impact of climate change on agricultural GDP of poor and highly agriculture-dependent economies is of considerable concern (Bobojonov and Aw-Hassan, 2014).

The rural community of Limpopo province places great emphasises on growing maize and vegetables. However, adverse climatic conditions will have a bearing on their agricultural production (Mpandeli et al., 2005).

2.4. Agricultural Crop Production Adaptation to Climate Change

Agricultural change does not involve a simple linear relationship between changes in a farmer's decision making environment and farm-level change. One important issue in agricultural adaptation to climate change is the manner in which farmers update their expectations of the climate in response to unusual weather patterns (Maddison, *et al*., 2006).

The importance of adaptation was reiterated in the Copenhagen Accord, 2012 which emphasizes that enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing
States and Africa.

In December 2015, the Paris Agreement adopted, after four years since the launch of the process to develop the legal instrument under the Ad hoc Working Group on the Durban Platform for Enhanced Action (ADP). The Agreement cover all the crucial areas identified as essential including mitigation, a transparency system and global stock take, adaptation, loss and damage as well as support including finance, for nations to build clean, resilient futures.

The impact of adaptation on farm productivity outcomes has been studied by Di Falco et al. (2011) in Ethiopia. The farmers who had reported adapting to climate change were more food secure:

adapters produced more than in the counterfactual case where they hadn't adapted. Similarly, predictions for non-adapters estimated that these farmers would gain as a result of adaptation.

One adaptation could be to change to the time that crop planting takes place. For instance, to counter rising temperatures, farmers could shift planting to cooler times of the year (Sultana *et al*., 2009). Similarly, changes in long term precipitation patterns would mean that it would be optimal for farmers to plant seeds earlier or later, depending on when the seasonal rains arrive.
Another important adaptation strategy is changing the variety or type of crop grown. For instance, a farmer facing an increased likelihood of drought may switch to faster maturing varieties of the same crop or may could switch into a deferent crop that is more tolerant to lower water availability (Lobell and Burke *et al*., 2010). The efficacy of crop switching to adapt to climate change has been studied by Kurukulasuriya and Mendelsohn (2008) using a Ricardian framework. They find that the crop switching can significantly lower the costs of climate change across African farms. Farmers may also change the input mix they apply to crops in response to past or expected climate change.

Numerous studies have cited the difficulty of obtaining credit as a crucial factor in determining the ability of farmers to adapt to climate change in other settings (Deressa *et al*., 2009; Maddison, 2007). Credit markets are an important feature of Pakistan's rural agricultural economy owing to the range of different types of lenders that offer credit (Aleem *et al*., 1990). Differential access to credit may be an important determinant of adaptation given that a number of adaptations require significant up-front investment that may have to be leveraged with credit.

Formal extension services may be one way in which farmers learn about new farming information. Earlier work by Hussain et al. (1994) concludes that the Training and Visit extension programme in Pubjab in the late 1980's was successful at encouraging the adoption of new agricultural technologies. Information may also be spread more informally through groups of neighbouring farmers or relatives.

South Africa's Climate Change Response strategy, 2012 suggests that adaptation measures should include: (i) Changes in agricultural management practices, such as a change in planting dates, row spacing, planting density and cultivar choice, and other measures, which would counteract the effects of limited moisture. Irrigation is currently used to supplement low levels of precipitation but this could become very expensive and less effective, giving conditions of increasing aridity.

(ii) A reduction of reliance on industrialised mono-cropping and diversification of the range of crops cultivated will reduce vulnerability as well as creating jobs and potentially reducing irrigation needs. Development of more and better heat and drought resistant crops would help fulfil current and future national food demand by improving production efficiencies in marginal areas, with immediate effect. (iii) Maintain a variety of seed types in seed banks that preserve biological diversity and provide farmers with an opportunity to make informed choices could be used to counteract the effects of climate change, maintain food security and establish possibilities for profitable specialisation.

2.5. Summary

In this chapter, the literature reveals climate change as a phenomenon which cuts across the entire globe. It reveals climate change being an average pattern of weather over the long term. It reveals the overview of climate change based on international, continental, regional and nation wise. Literature reveals that the Crop models are also useful tools to assess impacts of climate change on crop production and explore adaption potential of crop. The causes of climate change and its impact on crop production based on international, continental, regional and nation wise were discussed. The impacts are negative, and it could be seen on food and agriculture and other various sectors which include: water resources, vulnerable populations, and national security among many others. It further explains the climate change in the study area and the level of awareness in few countries in Africa.

The chapter also assess the crop production adaptation response to future climate change in other sectors like water resource, etc. which are expected to develop greater capacity to manage risk, uncertain conditions and, therefore, to adapt more readily to new and different conditions.

This chapter reflects on concepts and understanding of climate change being an average pattern of weather over a long term. It also highlights the causes and the consequences of climate change. Climate change has been perceived in terms of extreme heat and floods, droughts and heavy rains, declining rainfall patterns, and rise in sea level. All these factors have a great impact on agriculture. The impacts are negative, and it could be seen on food and agriculture, health, water resources, ecosystems, shelter, vulnerable populations and national security. The chapter further explains the future climate change in the study area and the level of awareness in many countries in Africa.

There is no doubt that the climate is growing warmer currently; indications of that change are evident around us. According to IPC (2012), the scientific community widely agreed that climate change is already a reality. The study of climate change cuts across many fields, which include geology, meteorology, and even oceanography. The United States Environmental Protection Agency (EPA, 2011) referred to climate change as any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Over the past century, surface temperatures have risen, and associated impacts on physical and biological systems are increasingly being observed (PRC, 2012). Climate change will bring about gradual shifts such as sea level rise, movement of climatic zones due to increased temperatures, and changes in precipitation patterns (Wang *et al.*, 2011).

In addition, as agreed by the majority of scientists, climate change is mainly driven by the emission of greenhouse gases, such as carbon dioxide, methane and nitrous oxide (IPCC, 2012). Among other sources of emissions, agriculture is one of the most important contributors. Agriculture is one of the most important sources of emissions of greenhouse gases and the sector is increasingly being recognized for its potential to be part of the solution (IPCC, 2007). According to Smith (2008), energy and chemical intensive farming led to increased levels of greenhouse gas emissions, primarily as a result of the over-use of fertilizers, land clearance, soil degradation, and intensive animal farming.

There is evidence that the climate has changed and is continuing to change. Three of the resulting changes of the climate are changes in precipitation, temperature and extreme events such as droughts and floods. The impact of climate change is felt by farmers mainly in the "timing, frequency and intensity of rainfall events, and in the distribution of these events within a season of growth" (Blignaut *et al*, 2009). Annual average temperature and precipitation are important in assessing climate changes but do not provide adequate indication of the impact these changes have on individual farmers.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the area where the study took place. It covers the area in square kilometres and where it is situated on the map .In addition, it also describes the research design and methodology of the study, including the population, sampling, data collection, data-collection instrument and ethical considerations. This section also briefly introduces the study location and highlights its biophysical attributes. According to De Vos (2011:27), quantitative researchers consult possible designs and select or develop one from the models available. In this study, the researcher selected a descriptive design to gain insight from the farmers to determine the level of awareness of the farmers about climate change on agricultural crop production in the Vhembe district municipality (VDM).

3.2 Research design

The researcher adopted a quantitative approach, using an exploratory and descriptive design to examine the impact of climate change on the agricultural crop production in the VDM. Quantitative research is one of the research approaches used in empirical investigations. It is defined differently by different authors (Leedy, 2011; Bless Higson-Smith, 2011). Unlike qualitative research, quantitative research involves the collection, analysis and interpretation of numeric data, collected through experiments or surveys, or through interviews using structured or unstructured questionnaires (Leedy, 2009). For the purpose of this study, this definition is adopted as a working
definition; that is, the collection, analysis and interpretation of quantitative data using structured farmers questionnaires. De Vos (2011:138) describes a research design as "an overall plan for conducting research".

The purpose of the quantitative research in this study is to determine the level of awareness of small scale farmers about climate change, Compare the level of production scale between the farmers who are aware and the farmers who are not aware of climate change, and identify the factors that influence the level of farmers' awareness to climate change.

3.3. Study area

The study area is the VDM, which is situation in the northern part of Limpopo Province. Vhembe is one of the five district municipalities of Limpopo: Waterberg, Sekhukhune, Capricon and Mopani, Parts of the Vhembe district were the former Venda homeland. The Vhembe District Municipality is composed of four local municipalities, namely; Makhado, Musina, Thulamela and Mutale (Figure 3.1). VDM shares the borders with three Southern African Countries: Botswana, Zimbabwe and Mozambique and it also has two neighbouring municipality Districts: Capricorn and Mopani District Municipalities. On the eastern side, it shares the border with the Kruger National Park. The Vhembe District Municipality covers 21,402 kilometres of land (Vhembe District Municipality IDP Report, 2011/2012).

The choice of the study area tended to bridge the gap and the level of awareness of the farmers about climate change on agricultural crop production in the rural areas as the farmers in the rural communities depend more on climate-sensitive livelihood activities and they have lower resources and social support systems compared to urban populations. As a result the farmers in the rural area are faced with the large potential impacts from future climate change events. The VDM is one of these rural municipalities where the farmers are faced with these challenges (lack of climate change awareness and adaptation, high poverty and low crop production) in South Africa. In addition, the choice of the study will also assist in evaluating how smallholder farmers in the rural area perceive climatic changes and how they cope with such conditions?.

In addition, the choice of the study will also assist in comparing the level of production scales between the farmers who aware and the farmers who are not aware of the climate change impacts and its threats.

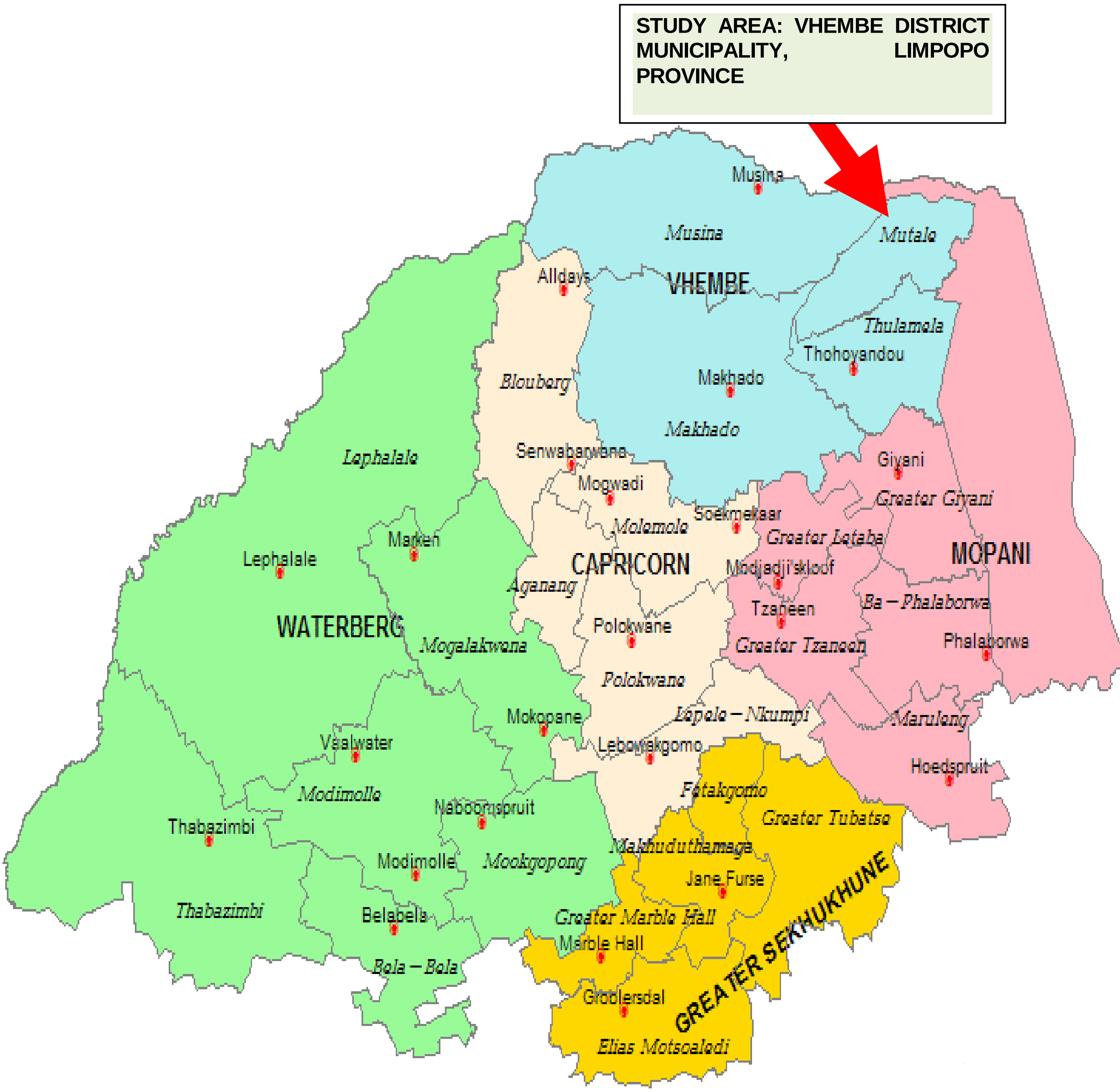


Figure 3.1: Geographic location of the Vhembe Districts Municipality, Limpopo Province (DLGH, 2009)

3.3.1 Population

The total population of the VDM is 1 294 722 and the density of 50.6 per km2 (131/sg mi) (Census 2011) and population was 1198 056 from 2001 Census and 1 240 035 from 2007 Community Survey. It reveals that from 2001 to 2007 the population of Vhembe has increased by

41 979 people, and 54687 from 2007 community Survey to 2011 Census. The population mainly comprises of 54,4% females, 45,5% males, with 51,3% of the population being under the age of 20 years, which is the general pattern in the VDM. The district population composition is further characterized by a predominantly young population with 75% at 35 years and below. Unemployment is estimated at >64% with a very disturbing poverty level of >71% which is primarily attributed to the rural nature and composition of the population.

3.4 Data Collection

Suitable interview date and times were arranged with farmers and permission was obtained from the district offices of the Limpopo Department of Agriculture. The researcher, together with extension officers from Vhembe, conducted the interviews. The local extension officers helped in collecting data because they had a better understanding of the area in terms of farmers that were prominent in agricultural crop production in the area of study.

The interviewers explained to the anticipated respondents the purpose of the survey, the importance of their participation and co-operation during the interviews. Interviews were conducted face-to-face with farmers.

3.4.1 Questionnaires

The total of 150 closed questionnaires were designed and distributed to the farmers during face-to-face interviews. Kitchen and Tate (2011:94) define closed questionnaires as where the respondent is given answers, one of which they must choose as the most representative of their facts/views. Questionnaires Data to be analysed quantitatively are usually generated using what are termed closed-ended questions.

There was a challenge of language barriers during the data collection as the Questionnaires were prepared in English and most of the local farmers in the VDC are Venda speaking, however the extension officers assisted the researcher with translating during data collection.

The questions in the questionnaires were numbered from page 1 to page 10 and they were divided into five sets: composition and characteristics of farm, crops cultivated, climate change issues, and adaptation measures. Each question was directed at obtaining answers in respond to three objectives indicated in Chapter 1 which are: understanding the impacts of climate variability and change on agricultural production in the VDM, assessing the impacts of climate variability and change on agricultural production in the VDM and identifying adaptation strategies that reduce the impacts of climate variability and change on agricultural production in the VDM.

3.5 Data Sampling

The purposeful sampling method used covered most of the productive farms in the VDM and also covered the uniform or homogeneous characteristics of farmers. The sample frame was designed to meet the objectives of the study and it had to adhere to the statistical specifications for accuracy and representatively.

Focus group discussions were conducted (see picture 4.1). Vhembe District selected crop farmers were interviewed in this study as they were in the majority in the study areas.

A total of 150 farmers were randomly selected within the VDM with the assistance of the Vhembe Agricultural senior manager and delegated the relevant extension officers.

Data was collected in January and February 2013 from VDM , Lımpopo, South Afrıca. Representative samples of 150 farmers were visited, using a self-administered questionnaire, containing both closed and open-ended questions. Closed questions were used to elicit background information and for statistical information about climate change and crop production, the type of crop production, climate change awareness and farmers support.

Open-ended questions were used to allow the respondents to give longer answers.

The questionnaire consisted of five (5) sections, namely

• Section A Demographical Information

• Section B Composition and Characteristics of Farm

• Section C Crops Cultivated

• Section D Land Characteristics

• Section E Climate Change issues

• Section F Adaptation Measures

The questionnaire was sent to both the supervisor and the statistician for comment and then amended according to their comments and then amended according to their comments. It was noted that 46 percent males and 54 percent females participated in the study. The study involved VDM (Table 4.3). In this study, all the completed questionnaires were returned thus giving a response rate of 100%.

After collecting data, the first step was to transfer it onto a spreadsheet using the Statistical Package for Social Sciences (SPSS) 17.0 version. According to Kumar (2010), it is important that the information obtained should be in the language that the computer will assimilate when a computer will be used to analyse the data.

3.6 Methods of data analysis

In analysing the data, variables that were the most representative of the study (impact of climate change on agricultural crop production in the VDM) were selected. Preliminary descriptive statistics of the variables selected were performed and further statistical analysis was conducted. Three types of analysis were employed in the study. They were Principal Component Analysis (PCA), Binary Logistic Regression Model (BLRM) and the Heckman Probit Model (HPM).

The PCA was used to identify groups of inter-correlated variables in order to examine hidden interrelationships amongst them. It was also used to get variables that represented different patterns of perceptions and adaptations by crop farmers in the area of study.

The BLRM was used to determine crop farmers' decision to adapt or not to climate change. This method has been used by researchers to analyse similar studies on agriculture farmers' choices in decision making on the impacts of climate change (Seo *et al.*, 2005).

The HPM was used to estimate the determinants of an individual crop farmer's decision to select adaptation. This model has been used in similar studies that determine adaptation to climate change (Maddison, 2007; Bayard *et al.*, 2006; and Deressa *et al*., 2011).

A statistician analysed and interpreted the data, using the SPSS program version 15. The results were presented in descriptive and inferential statistics, such as frequency tables with percentages. This chapter discusses the data analysis and interpretation with the assistance of frequency tables and bar charts (Manzini, 1998:238). The bar charts are presented in a horizontal format. The N value indicates the number of respondents for each question

CHAPTER 4

Data analysis and interpretation

4.1 Introduction

Chapter 3 has introduced the research methods and established its purpose and relevance for this study. Relevant methodological issues such as study area, farmers sampling, questionnaire design and the data collection process were discussed in detail. Chapter 3 has also presented a detailed descriptive statistics of the data that will be used for the analysis of farmer's participation in the impact of climate change on agricultural crop production in VDM.

This chapter discusses the data analysis, interpretation, and findings on the impact of Climate change on agriculture crop productıon in VDM, Lımpopo, South Afrıca. The aim of data interpretation is to learn more about the population from which the sample is drawn (De Vos *et al*., 2012:218).

In general terms, agriculture production depends on climate conditions, such as temperature, evaporation and the amount of rainfall. The climate is a primary determinant of agricultural productivity, any significant changes in climate in the future will influence crop productivity, hydrologic balances, input supplies and other components of managing agricultural systems: (Adams *et al*., 1998).

4.2 Respondents' demographical data analysis

The demographical data covered the respondents' ethnic group, language, age, gender, marital status, breadwinner, family member supporting farming activities, choice and type of support, number of children, level of education, and medium of instruction in teaching.

Table 4.1: Summary characteristics of sample

Sample	Number of farmers	Percentages
Number of farmers per district		
Vhembe district	150	100
Total	**150**	**100**
Number of farmers per local municipality		
Mutale local municipality	150	100
Total	**150**	**100**
Number of farmers per village		
Folovodwe	125	83
Rambuda	25	17
Total	**150**	**100**

The 150 farmers samples were interviewed (Table 4.1) on their awareness and perceptions of climate change, and trends that include, food production, temperature among other climate induced factors influencing their livelihood within the VDM, where 125 farmers sample were conducted from Folovhodwe farmers and Rambuda farmers (all these farmers) are under Mutale Local Municipality which is under VDM .

The choice of VDM for the intensive field studies was considered appropriate because of the population of 1 294 722 and this population depend on the local crop production for survival (Census 2011) . The VDM is responsible for crop production which contributes to social-economic in the rural area which resemble the important of small-scale farming in rural areas and the impact of climate change on crop production.

This confirms the finding of Kalaugher (2010), which indicate that the crop production depends on the climatic variability of the area. According to Nadler (2014), the most important way of ensuring that crop production remains sustainable is to ensure that crops and cropping systems match the climate of the location.

4.3. Age Profile Data Analysis

The respondents ranged from under 18 to over 60 years old (see Table 4.2). Of the respondents, 6.7% (n=10) were under 35; 11.3% (n=45) were between 36 to 45 years ; 44.7% (n=67) were between 46 to 60; 37.3% (n=56) were older than 60.

Table 4. 2: Age of farmers

Age	Number of farmers	Percentages
18 - 35	10	6.7
36 - 45	17	11.3
46 - 60	67	44.7
60 >	56	37.3
Total	**150**	**100**

Looking at the farming activities, most farmers fall in 46 – 60+ age group as indicated in Table 4.2 and this can be as the result of lack of interest in agricultural production from other age categories.

Based on the result (Table 4.2), The young people between 18 and 35 yers in the Vhembe District revealed that Crop Production is the last career or job choice. These age group believed that crop production remains an old fashioned sector, a sector that cannot generate income for their living, this group considered the government social grants as a secure source of livelihood than farming. The worrying factor is that the Farmer populations are ageing rapidly in the Vhembe District.

According to Asiti *et al*., (2010) age is positively related to some climate change adaptation measures and experiences. Most farmers in VDM assume that old age is associated with more experience. The study confirm the finding of Asiti, (table 4.2) , the researcher confirm that the people between the age of 46 to 60 in VDM are in farming and have more experiences than other age groups.

4.4. Gender Profile Data Analysis

Of the respondents, 46.0% (n=69) were Males and 54.0% (n=81) were Females (see Table 4.3). This gender distribution confirms the domination of Female in the rural farming compared to the Male.

Table 4. 3: Gender of farmers

Gender	Number of farmers	Percentages
Male	69	46
Female	81	54
Total	**150**	**100**

Various studies have shown that gender is an important variable affecting adaptation decisions at the farm level. According to Bayard *et al.,* (2007) female farmers are more likely to adopt natural resource management and conservation practices. According to Nhemachena and Hassan (2007), the possible reason for female to adapt is that in most rural smallholder farming communities, male are more often based in towns, and much of the agricultural work is done by Female.

Therefore, Females have more farming experience and information on various management practices and how to change them, based on available information (Anim, 2005). It was also noted that Female spends most of their time in the field than men (StatsSA, 2007).

The research result (Table 4.3), confirm the finding of Hassan and Nhemachena,the 54% in VDM are female compare to the 46% of male. Therefore, the Females are majority and adopt easy.

4.5. Number of years in Farming

Of the respondents participated ranged from 1 to over 50 number of years in farming (see Table 4.4). Of the respondents, 3.3% (n=5) under 5 years; 14.7% (n=22) were between 6 to 10 years ; 49.3% (n=74) were between 11 to 20 years ; 18% (n=27) were between 21 to 49 year and 14.7% (n=22) older than 50 Number of years in farming .

Table 4. 4: Number of years in farming

Years	Number of farmers	Percentages
1- 5	5	3.3
6-10	22	14.7
11- 20	74	49.3
21 - 49	27	18
50 >	22	14.7
Total	**150**	**100**

The results show that a higher proportion of farmers with more than 11 to 20 years of experiences with a total of 49,3% ,and followed by farmers with more than 21 to 49 years' experiences in crop production. Those farmers that have more than 11 years experiences claimed that temperature is increasing and rainfall is decreasing, and noted change in the frequency of droughts and floods. Farmers with less than 10 years of experience are claiming that no change in the temperature and no change in rainfall.

However, the Kruskal-Wallis (2005) test indicated that the views of the experienced farmers is very important and significant compare to inexperienced farmers

The result (table 4.4) confirm the Kruskal finding, the 49.3% in VDM are have significant experience to determine and understand the climate change treads and impact on the crop production.

4.6. Employment Status

Of the respondents participated ranged from:91.3% (n=137) farmers are full time farming, 3.3% (n=5) farmers are working part-time , 1.3% (n=2) farmers are unemployed fulltime, 3.3% (n=5) farmers are student, 0.7% (n=1) farmer is a housewife (see Table 4.5).

Table 4.5: Employment status

Employment	Number of farmers	Percentages
Farming full-time	137	91.3
Working part-time	5	3.3
Unemployed	2	1.3
Student	5	3.3
Housewife	1	0.7
Total	**150**	**100**

Looking at the farming activities, the high percentage (91%) of the farmers are full-time employment as indicated in Table 4.5 and this shows that the smallholder farming communities depend on crop production for employment, livelihood source and income.

From the table 4.5,the 3.3% of the farmers are part-time farmers as they are working full time as the school teachers and 1.3% of young people regarded farming as unemployment.

According to Nhemachena and Hassan (2007), the possible reason for farming full-time in the rural smallholder farming is the socioeconomic factors; the local economy in the most rural area depend on the crop production.

The finding from table 4.5 confirm that 91,3% farmers are full time and contribute to the socioeconomic in the VDM.

4.7. Education level

Of the respondents participated ranged from:8.0% (n=12) farmers have no schooling, 76% (n=116) farmers have primary education completed , 5.3% (n=8) farmers have some secondary education, 4.7% (n=7) farmers have secondary education completed,4.7% (n=7) farmer have post-secondary education (see Table 4.6).

Table 4.6: Education level

Education Level	Number of farmers	Percentages
No Schooling	12	8
Primary Education Completed	116	76
Some Secondary Education	8	5.3
Secondary Education Completed	7	4.7
Post-Secondary Education	7	4.7
Total	**150**	**100**

According to Maddison (2007) , educated and experienced farmers are expected to have more knowledge and information about climate change and adaptation measures to use in response to climate challenges, he further indicate that the education and employment are important factors influencing decision to adapt. The majority of the farmers in the study have completed primary education (76 percent)

4.8. Land Tenure System

The respondents participated:5.3% (n=8) farmers are privately owned land and 94% (n=141) farmers are communal owned land (see Table 4.7).

Table 4.7: Land Tenure System

Land Tenure	Number of farmers	Percentages
Privately Owned	8	5.3
Communal Land	141	94
Total	**150**	**100**

The results (Table 4.7) show that a higher proportion of farmers are farming under communal land (94%), this mean that these farmers do not have tenure security. According to Maddison (2007),the communal land farmers will not/likely to access insurance and credit compared to privately owned land farmers, small farmers have limited access to financial instruments, such as credit and insurance, to hedge against climatic risk, leaving the poor and the marginalised exposed and more vulnerable.

4.9. Farm Ownership

Of the respondents participated:9.3% (n=14) farmers are managed by the individual, 90% (n=135) farmers are managed by the family members and 0.7% (n=11) farmers are managed by the individual (see Table 4.8).

Table 4.8: Farm ownership

Farm owner	Number of farmers	Percentages
Individual	14	9.3
Family Member	135	90
Farmers Group	1	0.7
Total	**150**	**100**

Based on the Table 4.8, farmers prefer to owner their own farm as the family not as a group or individual. According to Shultz *et al.,* (2008) land ownership, individually managed is widely believed to encourage the adoption of technologies linked to land such as irrigation equipment or drainage structures. Even though the Land is 94% communal, the family nominate the family member to own the land in order to take full responsibility of the farm.

4.10. Farm Acquisition

Of the respondents participated:1.3% (n=2) farmers are own finance acquisitioned,0.7% (n=1) farmer is bond acquisitioned, 95.3% (n=143) farmers are inheritance acquisitioned from the families and 2.7% (n=4) farmers are acquisitioned as donation or other means (see Table 4.9).

Table 4.9: Farm acquisition

Farm acquisition	Number of farmers	Percentages
Own finance	2	1.3
Bond	1	0.7
Inheritance	143	95.3
Other	4	2.7
Total	**150**	**100**

Most Farmers in the Vhembe District were acquired through inherited their farms from their forefathers .This was contribution of land redistribution done by former Venda homeland.

4.11. Source of Information

Of the respondents participated:0.7% (n=1) farmer depend on Flyers for source of Climate change information,0.7% (n=1) farmer depend on magazine for information,0.7% (n=1) farmer rely on local newspapers for source of information ,and 97.9% (n=147) farmers depend on Radio for climate change information ,specific SABC Radio (Phalaphala Fm)(see Table 4.10).

Table 4.10: Source of Information

Source of Information	Number of farmers	Percentages
Flyers	1	0.7
Magazine	1	0.7
Local Newspapers	1	0.7
Radio	147	97.9
Total	**150**	**100**

According to Lobell and Burke (2010), Radio is still the most effective way of reaching rural farmers as the adaptation measures to climate change.

4.12. Form of Extension Service Available

Of the respondents participated:42% (n=63) farmers depend on formal extension provided by Vhembe Department of Agriculture ,3.3% (n=5) farmer rely other farmers for extension service,0.7% (n=1) farmer rely on family support for extension services , 0.7% (n=1) farmer rely on Neighbours for extension services , 0.7% (n=1) farmer depend on Municipal Office for extension services and 52.7% (n=79) farmers were not clear identified where they are getting the form of extension service (see Table 4.11).

Table 4.11: Form of extension service available

Extension Service	Number of farmers	Percentages
Formal Extension	63	42
Farmer to Farmer	5	3.3
Family Support	1	0.7
Neighbors	1	0.7
Municipal Office	1	0.7
Not Available	79	52.7
Total	**150**	**100**

Looking at the farming activities, the high percentage (52%) of the farmers were not clear where they get the extension services. The results indicate that 42% of farmers receive their extension services from Limpopo Department of Agriculture in Vhembe Offices as indicated in Table 4.11.

The total of 42% farmers in the Vhembe District have access to the formal extension (Table 4.11),The Farmers in Vhembe do not believe that humans behaviour are the primary cause of climate change, therefore ,they believe that direct outreach (e.g., meetings and workshops) to farmers can be more effective when the message focuses not on climate change, but instead on agricultural vulnerabilities to increased weather variability and extreme weather, and adaptive management strategies.
According to Adesina *et al*., (2006) the access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills. But it is still a worrying factor as the 52.7% of the farmers still did not understand how and where they can get the extension services.

4.13. Climate Change Support

Of the respondents participated: 0.7% (n=1) farmers depend on formal credit for Climate Change Support service ,1.3% (n=2) farmers rely on insurance for Climate Change Support service,44.7% (n=67) farmers rely on Subsidies from Vhembe Department of Agriculture for Climate Change Support service , and 53.3% (n=79) farmers were not clear where they received their climate Change support (see Table 4.13).

Table 12: Climate Change Support

Support	Number of farmers	Percentages
Formal Credit	1	0.7
Insurance	2	1.3
Subsidies	67	44.7
Not Available	80	53.3
Total	**150**	**100**

According to Kandlinkar and Risbey (2000) since most farmers in Africa are operating under resource limitations: (a) Lack of credit, (b) Subsidies and (c) Insurance will accelerate farmers' failure to meet transaction costs necessary to acquire adaptation measures as a result of unexpected weather patterns

4.14. Changes in Rainfall observed

At least 54 percent of farmers observed decreased rainfall as indicated in table 15, 8.7% (n=13) farmers observed increase rainfall, 4% (n=6) farmer experienced changing in timing of rainfall on the farmers, 32.7% (n=49) farmer observed the frequency drought and 0.7% (n=1) farmer not show if they observed or received any increased of rainfall or drought (see Table 4.13).The decrease in rainfall in the area could mean low agricultural production, low crop yields, poor quality of agricultural products etc.

Table 4.13: Changes in Rainfall observed

Rainfall	Number of farmers	Percentages
Increased Rainfall	13	8.7
Decreased Rainfall	81	54
Changes in timing of rainfall	6	4
Frequency of Drought	49	32.7
Not applicable	1	0.7
Total	**150**	**100**

The results show that a higher proportion of farmers with more than 11 to 20 years of experiences with a total of 49,3% ,and followed by farmers with more than 21 to 49 years' experiences in crop production.

4.15. Temperature changes observed

Of the respondents participated: 96% (n=144) farmers observed increase of temperature and 4% (n= 2.7) farmers experienced the decreased of temperature and 1.3 percentages experienced the decreased of rainfall (see Table 4.14). Only few farmers believed they observed the temperature decreasing, which is an indication that there is increase in the temperature which will have the major impacts on both the crop and livestock commodities, for example, rate of evaporation will increase, crops will also require more water.

Table 4.14: Temperature changes observed

Temperature changes	Number of farmers	Percentages
Increased temperature	144	96
Decreased temperature	4	2.7
No Observation	2	1.3
Total	**251**	**100**

4.16. Experienced the following lately

Of the respondents participated: 90% (n=135) farmers experienced drought, 0.7% (n=1) farmer experienced abnormal wind, 8% (n=12) farmer experienced floods, and 1.3% (n=2) farmer observed the frost (see Table 4.15).

Table 4.15: Experienced the following lately

Variable	Number of farmers	Percentages
Drought	135	90
Abnormal wind	1	0.7
Floods	12	8
Frost	2	1.3
Total	**150**	**100**

The results from Table 16 indicate that 90% of the farmers are lately experienced drought as part of climate variability.

4.17. Climate change on food security

Of the respondents participated: 27.3% (n=41) farmers are unemployed from other formal sector, 77% (n=51.3) farmers experienced low income, 18.7% (n=28) farmers experienced scarcity of food,1.3% (n=2) farmers experienced the increased of food price and 1.3% (n=2) farmers experienced lack of local markets (see Table 4.16).

Table 4. 16: Climate change on food security

Variable	Number of farmers	Percentages
Unemployment	41	27.3
Low income	77	51.3
Scarcity of food	28	18.7
Increased food prices	2	1.3
Lack of local markets	2	1.3
Total	**150**	**100**

The above results are in line with the third assessment report of intergovernmental panel on climate change which identified a range of impacts associated with climate variability and change. This included (a) low income, (b) increased unemployment and(c) reduced soil fertility for farmers and households (IPCC, 2007)

4.18. Perception on climate change

Of the respondents participated: 43.3% (n=65) farmers believed that planting of different crops can assist to adapt with the climate change, 12.7% (n=19) farmer believe that planting different varieties to adapt with climate change, 13.3% (n=20) farmers have perception that they can use crop diversification as the way to adapt with climate change,15.3% (n=23)farmers believed that use different planting date ,8% (n=12) farmer believe that shorten growing season can assist on climate change, 0.7% (n=1) farmer believe that change use of fertilizers, chemical and pesticides can assist on climate change , 0.7% (n=1) farmers have perception that using insurance as the way to adapt with climate change , 1.3% (n=2) farmers believed that prayer can assist to adapt with the climate change and 4.7% (n=7) farmer have perception that no adaptation is required for climate change (see Table 4.17).

Table 4.17: Perception on climate change

Perceptions	Number of farmers	Percentages
Plant different crops	65	43.3
Plant different varieties	19	12.7
Crop diversification	20	13.3
Use different planting dates	23	15.3
Shorten growing season	12	8
Change use of fertilizers, chemicals & pesticides	1	0.7
Use insurance	1	0.7
Prayer	2	1.3
No adaptation	7	4.7
Total	**150**	**100**

4.19. Crops affected by climate change

Of the respondents participated: 99% farmer's crops are affected very bad by the climate change and 1% farmer's crops are affected very bad by the climate change (see Figure 3).

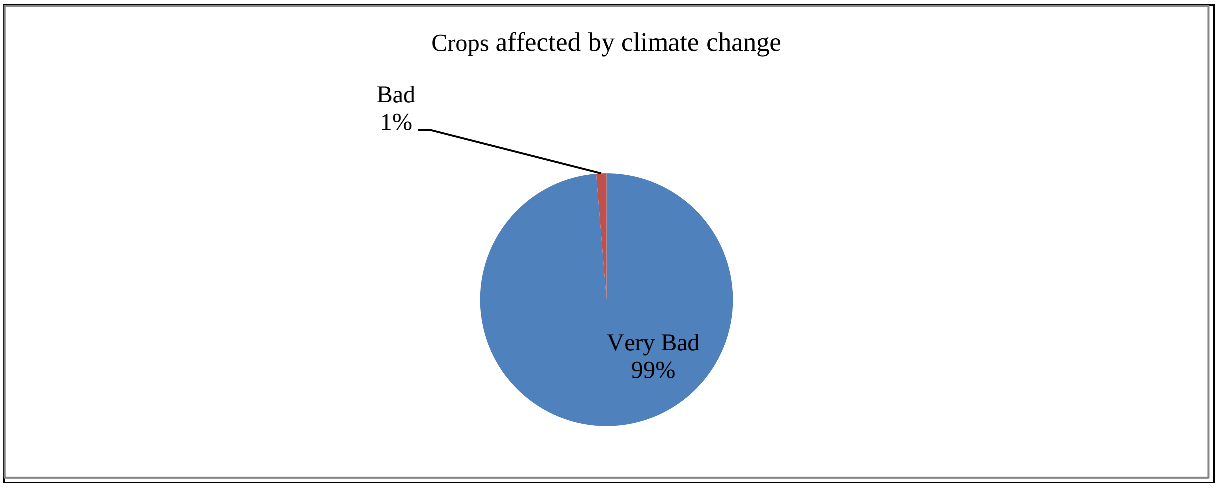


Figure 3: Crops affected by climate change

The impact of the climate change affect crop production which lead to the reduce food security and livelihoods.

4.20. Climate change impact on livelihood

Vhembe District Municipality experienced 68% and 32% of the farmers experienced low income (see Figure 4). Below results in line with the decrease of rainfall (table 15) and increase of temperature (table 16) observed in the Districts.

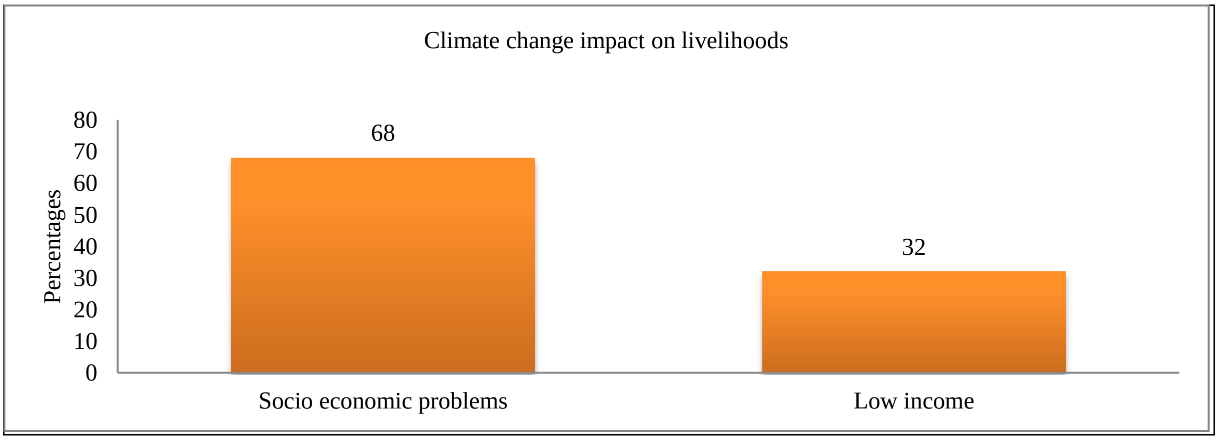


Figure 3: Climate change impact on livelihood

4.21. Climate Change Impact on agricultural production

Based on farmer's response in the reduction of crop yields 74%, the reduction of the land fertility by 17% and the diseases crop increased by 9% (see Figure 4.3).

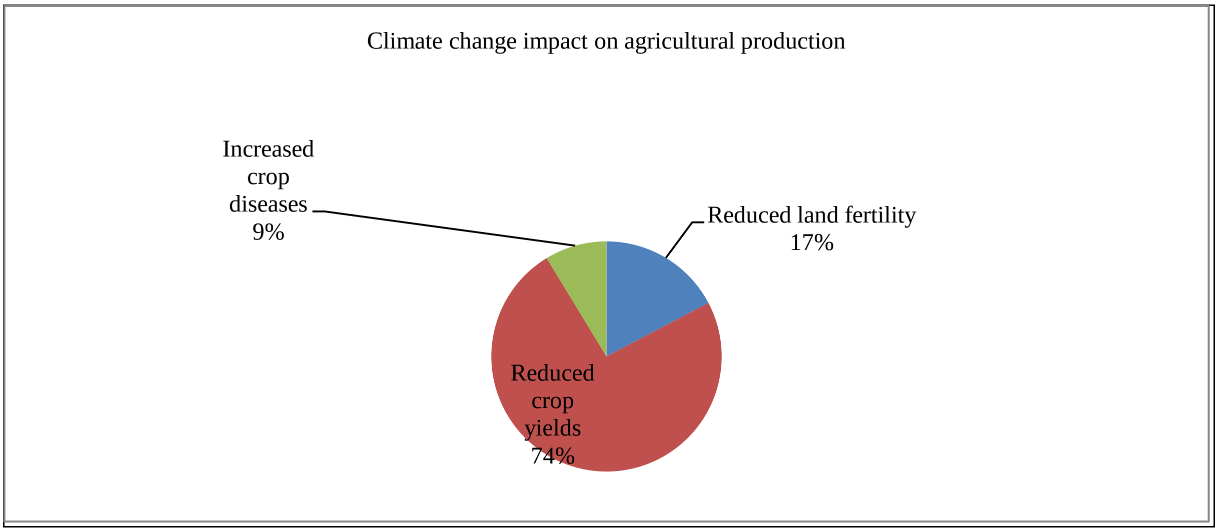


Figure 4: Climate Change Impact on Agricultural Production

The reduction of crop yields have impact on Agricultural Production ,it also indicated by study in Limpopo , Mpandeli (2006) found that the impact of lower rainfall has negative effects on the agricultural sector and low rainfall will result in (a) Decreases in agricultural activities, (b) Loss of livestock, (c) Shortage of drinking water, (d) Low yields and shortage of seeds for subsequent cultivation**.**

4.22. Access to Extension Service

Of the respondents participated: 53% farmers are not aware of climate change information and 46% farmes are aware of climate change information (see Diagram 4.2).

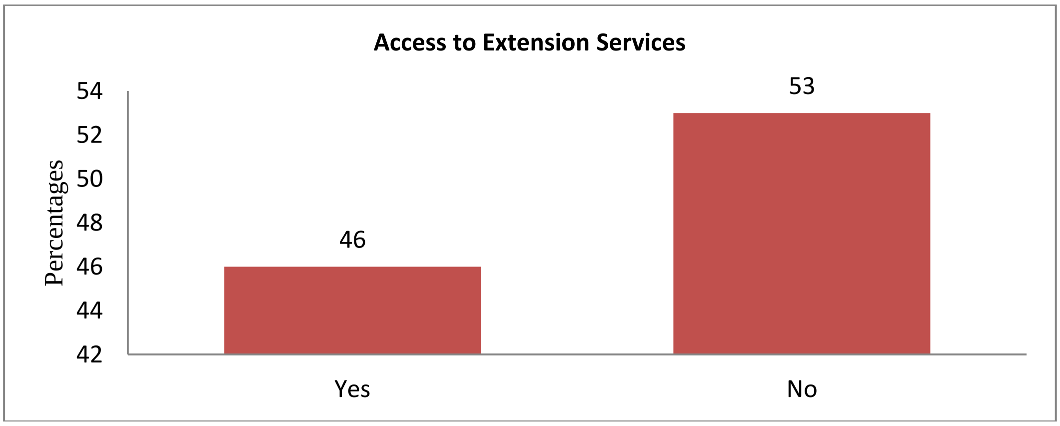


Figure 5: Access to Extension Services

Extension services is the most important for analysing the adaptation decisions.it further hypothesized that access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills.

4.23. Adaptation to Climate Change

Of the respondents participated: 70.7% farmers are not aware of climate change information and 18.3% farmes are aware of climate change information (see Figure 4.2).

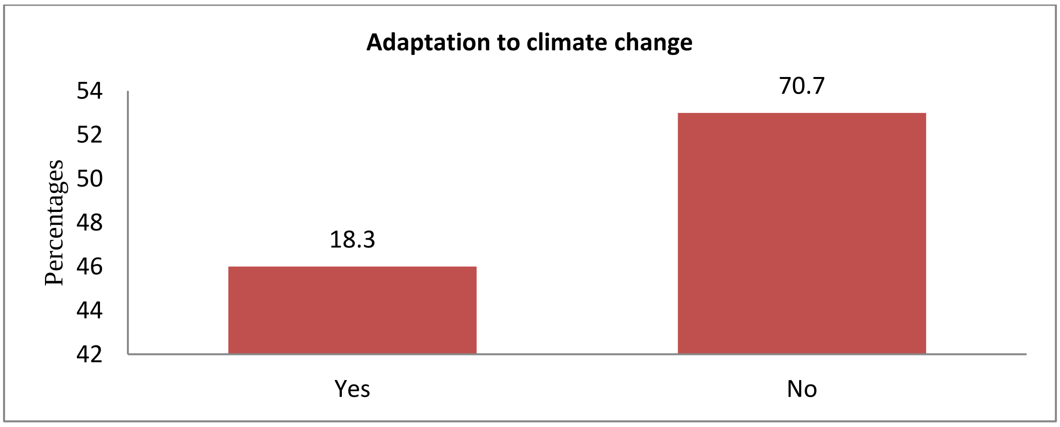


Figure 6**: Adaptation to climate change**

According to Vogel *et al*, (2005) the most important thing to adapt against changing weather patterns is to strengthen social, economic and environmental resilience of the most vulnerable communities.

4.4 Summary

Results indicate that farmers are aware that Vhembe District Municipality is getting warmer and drier with increased frequency of droughts, changes in the timing of rains, observed trends of temperature and precipitation. In this chapter farmers also identified that lack of information about climate change and variability, lack of information through extension services, poor adaptation capacity, and lack of Climate Change awareness as important constraints in the farmers.

The results also indicated that there is a temperature change where the rain days were few and there was increase in non-rain days. There were more warm days than cool days. This means that rainfall amounts to grow crops is generally lacking, a situation that can be further complicated by unpredictable onset and cessation.

The result also found that the empowerment and participation of women to be critical for the success of sustainable livelihood activities that serve as de facto options for adapting to climate change in the communal farm for crop production in the rural area.

Farmers' perceptions of climatic variability are in line with climatic data records. Indeed, farmers in the Vhembe District Municipality are able to recognize that temperatures have increased and there has been a reduction in the volume of rainfall. Farmers with access to extension services are likely to perceive changes in the climate because extension services provide information about climate and weather. Having access to water for irrigation increases the resilience of farmers to climate variability; therefore, they do not need to pay as much attention to changes in the patterns of rainfall and temperature. With more experience, farmers are more likely to perceive change in temperature.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary and Discussion

The previous chapter gave a detailed analysis of the methodology and research techniques used to conduct this study. This chapter presents the summary and conclusion . Chapter 1 outlined the main aim of the study as an investigation of the impact of climate change on the crop production in Vhembe District Municipality, Limpopo, South Africa. The interest in the study was influenced by the needs of the farming community in the Vhembe District Municipality, It also influenced by the fact that the majority of the farmers in the Vhembe District Municipality are vulnerable and have low adaptability capacity due to the threats posed by climate variability and changed. This study focused on the impact of changes in climatic conditions
on crop production, it is also motivated by the fact that crop production is the mainstay of local economy in Vhembe District Municipality .

5.2 Summary of findings

The findings also suggest that the perceptions of climate change impact are more influenced by socioeconomic pressure than actual manifestation of climatic events. In addition, we observed that the perceived effect of climate variability and change on forest products used for livelihood varied significantly across the municipalities. Understanding these factors is essential when developing initiatives for climate risk management through forest management in the study communities. Forest development initiatives that target identified vulnerable forest products in each area can deliver immediate and effective forest and climate change management benefits to the study communities.

In summary, the study concludes that there is a low level of farmers awareness about the impact of climate change on the crop production in Vhembe district municipality. This low level of awareness translates into a low level of crop production which results in increased socio-economic problems, low income, increased unemployment, increased crops diseases and reduced crop yields as the researcher finding on Table 4.14 to 4.20.

5.3 Recommendations

The findings of the study have some very relevant implications for the planning and execution of climate change programmes in Vhembe district municipality, and lead to the following recommendations:

1. The proposition of providing more climate change services for farmers in the district is recommended. This will give incentives to farmers to participate in climate change adaptation programmers. This recommendation is strongly emphasised by 47 percent of the entire respondents, who are of the opinion that the provision of climate change awareness and extension services by local authority is a critical constraint to participation in climate change adaptation programmers by the masses (figure 4.2).

2. Finally, it is recommended that the existing national climate change response policy recognizes the above recommendations and incorporate them into their climate change adaptation strategies. The current efforts of the Department of Environmental Affairs (DEA), as outlined in the 'White Paper on National Climate Change Response' can form a critical basis for realizing these recommendations.

REFERENCES

Adams, (1998).The impact of climate influence crop and livestock productivity, hydrologic balances, input supplies and other components of managing agricultural systems.

ARC-ISCW (Agricultural Research Council-Institute for Soil, Climate and Water),2014. Seasonal Climate Forecast Information.

Alila and Atieno,2006. Adapting African Agriculture to Climate Change: Transforming Rural Livelihoods.

Anderson J, Bausch C (2006) Climate change and natural disasters: scientific evidence of a possible relation between recent natural disasters and climate change.

Anderson, J.J., 2007. Rainfall-runoff relationships and yield response of maize and dry beans on the Glen-Bonheim ecotope using convectional tillage and in-field rainwater harvesting. Ph.D thesis, Department of Soil, Crop and Climate Sciences, University of Free State, Bloemfontein, South Africa.

Asiti,W.2010. Smallholder Farmers'Perception of impact of Climate Change and Variability on Rain-fed Agricultural Practices in Semi-arid and Sub-humid Regions of Kenya.

Barcena.2014.Climate Change Risks and Adaptation: linking Policy and Economics

Blignaut , 2009. The impact of climate change and variability on precipitation and temperature

Bobojonov,Hassan,AW.2014.Agricultural transformation and production trends in the context of Climate Change in Centra Asia.

Boko, M. 2007. Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of IPCC.

Canadian Climate Programme Board, 2011.Climate change and Canadian impacts: the scientific perspective.

Calzilla,2013.South Africa Climate Change Respond Strategy

Challinor, 2015. The important of crop production and impact of climate change in the developing countries.

Cruz, R.V, 2007.Asia.Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.

DAFF (Department of Agriculture, Forestry and Fisheries), 2010-2013. Abstract of Agricultural statistics,2010-2013. National Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa.

DEA (Department of Environmental Affairs),2011.National Climate Change Response Policy.

Du Toit,2002.Climate Change,the Food Energy Water Nexus and food security in South Africa.

Easterling , 2012.Climate Change and Food Security: Health Impact in Developed Countries.

ERC (Energy Research Centre) , 2007. Climate change mitigation poses significant challenges for South Africa.

Eriksen.S,2011.Smallerholders Farmers'Perceptions of Climate change and Conservation Agriculture.

FAO (Food and Agriculture Organization of the United Nations) ,2010-2013.Climate change and food security: risks and responses - Food and Agriculture.

Hall Spacy, 2009.Vulnerability of National Economies to the Impacts of Climate Change in Asia .

Hope 2009:456.Climate change as silent disaster in Rural Communities.

Integrated Development Plan (IDP)-Vhembe District Municipality, 2012-2013, Office of the Mayor, Vhembe District Municipality.

IFAD (International Fund for Agricultural Development).2009-2011: Agriculture and Rural Poverty in Developing Countries and Underdeveloped Countries.

IFPRI (International Food Policy Research Institute) ,2009.Climate change: Impact on agriculture and costs of adaptation.

IPCC (Intergovernmental Panel on Climate Change): Extreme Weather and Climate Change .2011.Working Group II Report (WGII).

IPCC (Intergovernmental Panel on Climate Change): Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.2012.A Special Report of Working Group I and II Report (WGI and II).

IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report (AR4), Working Group I Report (WGI). 2007. Climate Change 2007: The Physical Science Basis.

James Blignaut, 2009. Agriculture Production's sensitivity to changes in climate in South Africa.

James J. McCarthy, 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability.

KPMG Kenya, 2012. Regional Economic Overview

Lam.J.C,2012.Impact of Climate change on energy use in built environment in different climate zones.

Letsatsi Duba, 2009. The impact of drought on food scarcity in Limpopo Province

Liverman and O'Brien, 1991.Predicted Effects of Climate Change on Agriculture: A Comparison of Temperate and Tropical Regions.

Lobell, D.B, 2015.Crops and Climate Change: Progress, trends, and challenges in simulating impacts and informing adaptation.

LTAS (Long Term Adaptation Scenarios),2013.Climate Trends and Scenarios for South Africa.

Mahapa, 2001.Evaluation of Crop Production Practices by Farmers in Tshakhuma ,Tshiombo, Rabali areas in Limpopo.

McCarthy , 2001. The impact of Climate Change on Crop production .

MFED (Ministry of Finance and Economic Development) in Ethiopian,2012.

Modida,2011.Exploring the Impact of Climate change on Children in South Africa.

Mpandeli, 2006. Managing Climate Risks using seasonal Climate Forecast Information in Vhembe District in Limpopo.

Musvoto,C ,2009.Southern Africa: Climate change to shrink Agricultural Production.

NDA (National Department of Agriculture),2009.Impact of Climate variability on Tomato production in Limpopo.

Nesamvuni,(2011). The Impact of Climate change and food insecurity in Vhembe District

Nhemachena ,(2008). climate change affect poor and Increased insecurity of livelihoods.

Smith, P, 2008.Greenhouse Gas Mitigation in Agriculture.

Schulze, (1995-2010). Factors Influencing Climate Change Vulnerability in Agriculture Sector.

Thomas,T. And M.Rosegrant.2015.Climate change impact on key crops in Africa.

Thornton,S.K, 2006-2009. Vulnerability and Adaptation to Climate Change in Semi-Arid Areas in East Africa.

Tshiala,M,F.2010.Impact of Climate Variability on Tomato Production in Limpopo Province.

Pelham,2009. Determinats of Climate change awareness level in upper Nyakach Division , Kisumu. Kenya.

Rosenzweig,Parry Martin,2011.Climate change ,global food supply and risk of hunger.

Wang, 2011. The Movement of climatic zones due to increased temperatures, and changes in precipitation patterns.

Weinberger , 2011. Mitigation of climate change improved farm management

World Bank, Hazard Management Unit, 2006.Disaster Risk Management no.6,Natural Disaster Hotspots Case Studies.

Woodward, 1987. Predicting the impact of climate change on the distribution of species: are bioclimate envelope models useful?

Oni SA, (2013-2016).Limpopo Provincial Climate Change Response Strategy

UNCC (United Nations Climate Change Conference) ,2015.COP 21.Greenhouse gases emissions mitigation, adaptation and finance from 2020.

UNDESA (United Nations Department of Economic and Social Affairs),2013 and 2014.World population Prospects.

APPENDIX A : QUESTIONNAIRE

My name is **Mr Musetha Mboniseni Aubrey**. Your Farm has been chosen to participate in this study and your contribution is very important. By answering our questions, you can help in planning future climate change adaptation options in South Africa. The answers that you personally give will be kept strictly confidential. They will be put together with everyone else's to give an overall picture. No-one will be able to know what you said as an individual, or what other members of your farm said. So please feel free to tell us what you think**.**

Date of interview:

Number:

Area

District Municipality	
Local Municipality	
Number of Years Farming in the area	

A.1 COMPOSITION AND CHARACTERISTICS OF FARM

Name	Birth date	Gender (please specify)	Relationship to Farmer	Employment status (codes at end of table)	Education Level (codes below)

Name	Birth date	Gender (please specify)		Relationship to Farmer	Employment status (codes at end of table)	Education Level (codes below)
Respondent 1. (Farmer)		M	F	XXXXXXXXXXX		
2.		M	F			
3.		M	F			
4.		M	F			
5.		M	F			
6.		M	F			
7.		M	F			
8.		M	F			
9.		M	F			
10.		M	F			
11		M	F			
12.		M	F			
13.		M	F			
14.		M	F			
15.		M	F			

Codes for employment status:	
Working full-time	1
Working part-time	2
Casual/piece jobs	3
Unemployed	4
Pre-school	5
Student (at school or further education)	6
Pensioner	7
Housewife taking care of home full-time	8

Codes for education:	
No formal schooling	1
Some primary education	2
Primary education completed	3
Some secondary school education	4
Secondary school education completed	5
Post secondary college education	6
Certificates / Short courses	7
University degree	8
Refused	9

Codes for Relationship to Farmer	
Father	1
Mother	2
Brother	3
Sister	4
Uncle	5
Other (specify)	6

A.2 CROPS CULTIVATED

What crops do you plant? Indicate by making a tick whether the crops are planted for:

		Own consumption	Mostly own, but small surplus is sold	Most of the harvest is sold
Grains				
	01			
	02			
	03			
Vegetables				
	04			
	05			
	06			
Fruit				
	07			
	08			
	09			
Other (specify)				
	10			

A.3 LAND CHARACTERISTICS

1. Type of Farm

Individual Farm	-1
Family Farm	-2
Community Farm	-3
Corporation/ Company Farm	-4

Tribal Farm	-5
Other (please specify)	-7

3. Who owns the farm?

Individual	-1
Family Members	-2
Farmers Group	-3
Corporation/ Company Farm	-4
Trust	-5
Other (specify)	-6

4. If you own the farm how did you acquire it?

Own Finance	-1
Bond	-2
LRAD	-3
PLAS	-4
Restitution	-5
Inheritance	-6
Other , specify	-7

B.1 CLIMATE CHANGE ISSUES

1. Do you receive information on climate change?

Yes	1
No	2

2. What is the source of information on climate change?

Flyers	-1
Magazines	-2
Radio	-3
Local Newspapers	-4
Internet	-5
Other (specify)	-6

3. Do you receive information on climate change through extension services?

Yes	1
No	2

4. Through what channel did you receive information on climate change?

Formal Extension	-1
Farmer to Farmer	-2
Family support	-3
Neighbours	-4
Municipal Office	-5
Other (specify)	-6

5. What kind of support do you receive for climate change impacts?

Formal credit	-1

Insurance	-2
Farmer to Farmer extension	-3
Relatives	-4
Subsidies	-5
Other (specify)	-6

6. What perceptions do you have on long-term temperature changes?

Increased temperature	-1
Decreased temperature	-2
Altered climatic range	-3
Other changes	-4
No change	-5
Other (specify)	-6

7. What perceptions do you have on long-term rainfall changes?

Increased rainfall	-1
Decreased rainfall	-2
Changes timing of rains	-3
Frequency of droughts	-4
Other changes	-5
Other (specify)	-6

8. Have you ever experience the following lately?

Drought	-1
Abnormal Wind	-2

Floods	-3
Frost	-4
Cold	-5
Other (specify)	-6

9. How has climate change affected your crops?

Very Bad	-1
Bad	-2
Slightly affected	-3
Not affected	-4
Other (specify)	-5

10. What impacts has climate change had on your livelihood?

Increased socio- economic problems	-1
Low income	-2
Increased unemployment	-3
Reduced cultivated lands	-4
Reduced cultivated practices	-5

11. What impacts has climate change had on agricultural production?

Reducing fertility of land	-1
Reduced crop yields	-2
Increased crops diseases	-3

Reduced livestock production	-4
Other , specify	-5

12. What impacts has climate change had on food security?

Unemployment	-1
Low income	-2
Scarcity of food	-3
Increased food prices	-4
Lack of local markets	-5

B.2 ADAPTATION MEASURES

1. Did you adapt to climate change

Yes	1
No	2

2. What are your perceived adaptations options?

Plant Different crops	1
Plant different varieties	2
Crop diversification	3
Use different planting dates	4
Shorten length of growing period	5
Move to different site	6
Change amount of land	7

Change crops to livestock	8
Change from farming to non farming	9
Increase irrigation	10
Change use of chemicals , fertilisers and pesticides	11
Increase water conservation	12
Soil conservation	13
Use Insurance	14
Use subsidies	15
Prayer	16
Other adaptation	17
No adaptation	18

3. What measures did you take to adapt to climate change?

4. If you did not adapt what made you not adopt adaptation measures?

5. What would you consider the most important message in a joint campaign on climate change adaptation?

6. What could you do yourself to pass these messages, to whom and how?

APPENDIX B: VHEMBE DISTRICT CLIMATE CHANGE DATA ANALYSIS OUTCOME

Table 1: Summary characteristics of sample

Sample	Number of farmers	Percentages
Number of farmers per district		
Vhembe district	150	100
Total	**150**	**100**
Number of farmers per local municipality		
Mutale local municipality	150	100
Total	**150**	**100**
Number of farmers per village		
Folovodwe	125	83
Rambuda	25	17
Total	**150**	**100**

Table 2: Age of farmers

Age	Number of farmers	Percentages
18 - 35	10	6.7
36 - 45	17	11.3
46 - 60	67	44.7
60 >	56	37.3
Total	**150**	**100**

Table 3: Gender of farmers

Gender	Number of farmers	Percentages
Male	69	46
Female	81	54
Total	**150**	**100**

Table 4: Number of years in farming

Years	Number of farmers	Percentages
1- 5	5	3.3
6-10	22	14.7
11- 20	74	49.3
21 - 49	27	18
50 >	22	14.7
Total	**251**	**100**

Table 5: Employment status

Employment	Number of farmers	Percentages
Farming full-time	137	91.3
Working part-time	5	3.3
Unemployed	2	1.3
Student	5	3.3
Housewife	1	0.7
Total	**150**	**100**

Table 6: Education level

Education Level	Number of farmers	Percentages
No Schooling	12	8
Primary Education Completed	116	76
Some Secondary Education	8	5.3
Secondary Education Completed	7	4.7
Post Secondary Education	7	4.7
Total	**150**	**100**

Table 7: Land Tenure System

Land Tenure	Number of farmers	Percentages
Privately Owned	8	5.3
Communal Land	141	94
Total	**150**	**100**

Table 8: Farm Management

Farm Management	Number of farmers	Percentages
Individual	13	8.7
Family Member	134	89.3
Farmers Group	3	2
Total	**150**	**100**

Table 9: Farm ownership

Farm owner	Number of farmers	Percentages
Individual	14	9.3
Family Member	135	90
Farmers Group	1	0.7
Total	**150**	**100**

Table 10: Farm acquisition

Farm acquisition	Number of farmers	Percentages
Own finance	2	1.3
Bond	1	0.7
Inheritance	143	95.3
Other	4	2.7
Total	**150**	**100**

Table 11: Source of Information

Source of Information	Number of farmers	Percentages
Flyers	1	0.7
Magazine	1	0.7
Local Newspapers	1	0.7
Radio	147	97.9
Total	**150**	**100**

Table 12: Form of extension service available

Extension Service	Number of farmers	Percentages
Formal Extension	5	3.3
Farmer to Farmer	63	42
Family Support	1	0.7
Neighbors	1	0.7
Municipal Office	1	0.7
Not Available	79	52.7
Total	**150**	**100**

Table 13: Climate Change Support

Support	Number of farmers	Percentages
Formal Credit	1	0.7
Insurance	2	1.3
Subsidies	67	44.7
Not Available	80	53.3
Total	**150**	**100**

Table 14: Univariate regression analysis of climate change adaptation determinants

Variable	**Total**	**(%)**	**OR [95%CI]**
Females	81	54	1.00[0.234 – 5.103]
			1
Age	150	100	1.00 [0.158 – 2.441]
			1
Decreased rainfall	81	54	1.10 [0.575 – 2.999]
			1
Some primary education	116	100	1.20[0.126 – 14.999]
			1
Farming fulltime	137	91.3	1.00 [0.127 – 2.112]
			1
Climate change info	148	98.7	1.01[0.76 – 3.555]
			1
Source of climate info	150	100	1.12[0.376 – 2.566]
			1
Perception on climate change	150	100	1.10[0.50- 3.011]
			1
Formal extension	5	3.3	1.20[0.68 – 3.44]
			1

OR= Odds ratio; 95%CI = 95% confidence intervals; 1< = no association; 1> = association

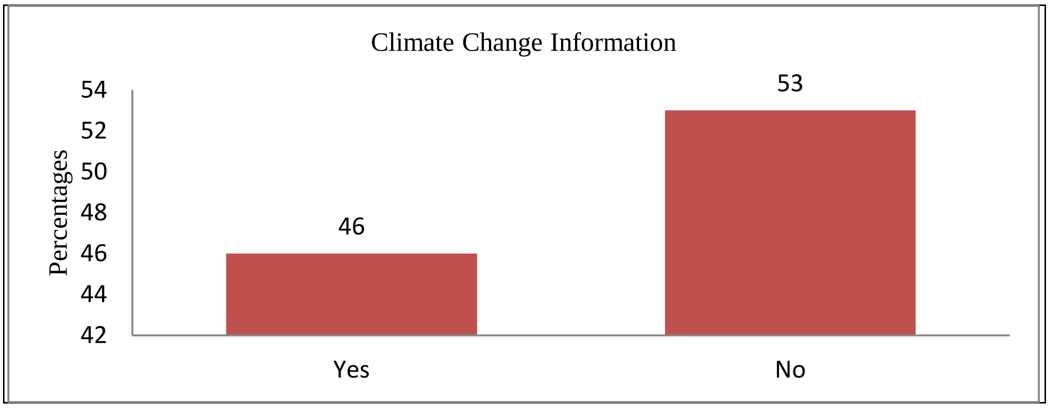


Figure 1: Climate Change Information

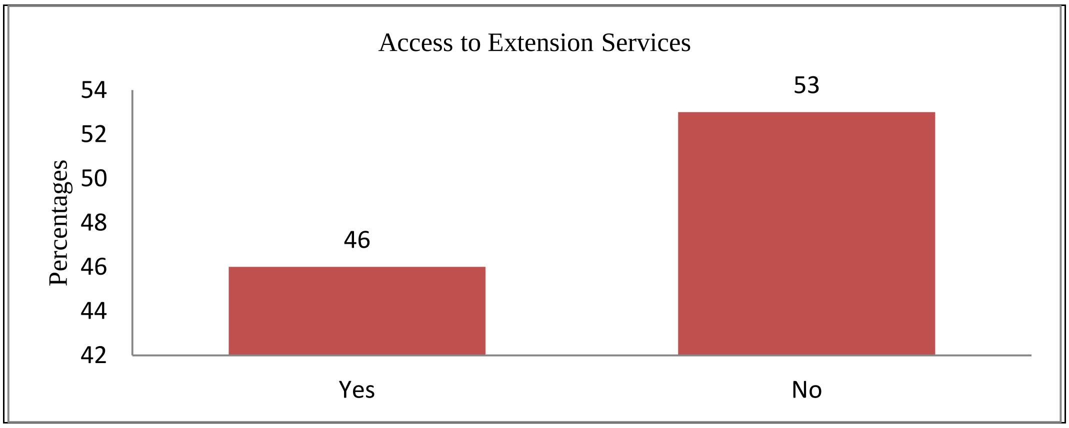


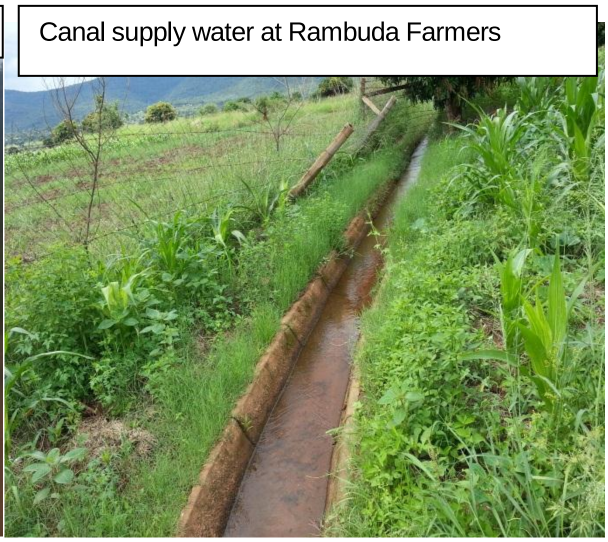
Figure 2: Access to Extension Services

APPENDIX C: PICTURE DURING DATA COLLECTION

The Student with the farmer during the presentation at Vhembe District

Mutale River Floods 16 January 2013

Canal supply water at Rambuda Farmers



The Student with the farmer during the presentation at Vhembe District


TOYOTA







APPENDIX D: UNISA ETHICS APPLICATION OUTCOME

APPENDIX E: CONSENT FORM

APPENDIX F: LETTER FROM VHEMBE MUNICIPALITY MANAGER