DETERMINANTS OF CLIMATE CHANGE ADAPTATION MEASURES AMONG CROP FARMERS IN LIMPOPO PROVINCE OF SOUTH AFRICA

By:

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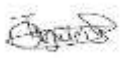
DEDICATION

This dissertation is dedicated to Almighty God, the author and finisher of my faith, the one who gave me strength and courage when I needed it most, I give all the glory and honor back to your name.

DECLARATION

I, Oluwatosin Mary Ogunsola, declare that "**DETERMINANTS OF CLIMATE CHANGE ADAPTATIONMEASURES AMONG CROP FARMERS IN THE LIMPOPO PROVINCE OF SOUTH AFRICA**" is my research work and all the sources that I have used have been acknowledged and cited as references. This research work has not been submitted before for a degree or as examination at any other University.

Signature: 

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LIST OF ACRONYMS AND ABBREVIATIONS

APSIM	Agricultural Production System Simulator
BLRM	Binary Logistic Regression Model
DAFF	Department of Agriculture, Fishery and Forestry
DEA	Department of Environmental Affairs
DSSAT	Decision Support System for Agro-technology Transfer
DWAF	Department of Water, Agriculture and Forestry
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHG	Green House Gases
IFAD	International Fund for Agricultural Development
IFPRI	International Food and Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
KPMG	Klynveld Peat Marwick Goerdeler
PCA	Principal Component Analysis
SADC	South African Development Community
STAT SA	Statistics South Africa
UNEP	United Nation Environmental Program
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
WWF	Worldwide Fund

ABSTRACT

Agricultural production is the main source of livelihood and food security for crop farmers especially the rural communities in the Limpopo Province of South Africa. This sector contributes immensely to the Gross Domestic Product (GDP) of the country as a whole, however, it is grossly affected by the impacts of changes in climate. Farmers take several and different adaptation strategies at different levels to help them cope with these changes in climate. It is therefore of great importance to have proper knowledge about the determinant factors that influences adaptation measures taken by the farmers. The purpose of this study was to analyze the determinant factors of climate change adaptation strategies in the Limpopo Province of South Africa.

Multistage sampling technique was used to collect data from 156 crop farmers (avocado and tomato farmers) selected from 3 districts (Capricorn, Vhembe and Mopani) in the Limpopo Province of South Africa. Structured interviews were scheduled with the farmers and questionnaires which contained both close-ended and open-ended questions were administered to the farmers. Proper explanation of what is entailed in the questionnaire was given to them and the questionnaires were filled with the help of the researcher for the purpose of the study to avoid deviating from answering the questions correctly.

The data collected was analyzed with the use of descriptive statistical tools and inferential analysis. Binary logistic regression analysis used to identify factors influencing the farmer's decision to adapt to the negative impacts of climate change. Cronbach alpha was also used to test the reliability and rigorousness of the data collected. The descriptive analysis revealed that a higher number of the participants are between the age of 46-55 years accounting for 29% of the total and are middle-aged people. Sixty-eight percent accounted for male participants, 32% as females. It also revealed that farming is the major occupation (73.7%) of the participants in the study area. Percentage of the farmers that were aware of climate change in their locality was 55.1% while 56.4% indicated that they received proper information on climate change in the study area. The findings also revealed that most of the farmers (70.5%) perceived that temperature has been on a significant increase over the years in their locality, 71.2% believed

that rainfall intensity is also changing while 50.6% explained that drought has been on the increase in the recent times.

The results of the Binary Logistic Regression analysis revealed that there is a significant relationship between source of income, educational level of the farmers, main occupation and climate change adaptation. These variables affected their decisions to take up adaptation measures. It also reveals the important adaptation strategies that the farmers have taken to help cope with changes in climate; multi-cropping (37.8%), use of different planting dates (41.7%), crop rotation (48.7%), use of soil conservation techniques (41%) and use of irrigation system (40.4%).

It is therefore recommended that certain adaptation measures should be subsidized for farmers especially the important ones that were employed by the farmers at the farm-level such as irrigation system, soil conservation techniques to mention a few. Also, government should provide better ways by which farmers can gain access to improved climate information and provide adequate extension services.

Keywords: Climate change, adaptation strategies, binary logistic regression model, avocado and tomato, crop farmers, Limpopo Province, South Africa.

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CHAPTER 1

INTRODUCTION

1.1 Background to the Study

Changes in climate is affecting the world and its effects is affecting the world's food system and the mode of living especially in the rural areas across the globe. Agricultural production such as crop and livestock management, fish farming, irrigation system and people's livelihood is being threatened by the occurrence of disasters such as floods, droughts, hurricanes, rising sea level and ocean acidification (FAO report, 2016). Sub-Saharan Africa has been reported to be facing a lot of problems associated with climate change most especially its crop farmers, this is due to the changing climate variabilities. Van Meijl *et al*., (2018) also suggested in their findings that changes in climate directly affects agricultural production as agricultural sector is exposed to the impacts of climate change. Despite the technological advances in the recent times, climate and weather are still the most important determining factors of agricultural productivity level across the globe. Low-input farming systems has been found to be evident in Sub-Saharan African countries due to the negative impacts of changes in climate (Jew *et al*., 2020; Sarkar *et al*., 2020).

World Bank, (2010) also reported that there has been a rise in temperature in South Africa in the last four decades with its monthly average minimum temperature ranging from 138^0C to 260^0C, this has led to increased warmer days and decreased cooler days. South Africa's average rainfall which was estimated at 450mm per year has fallen below the average of 860mm (World Bank, 2010). This shows that from 2010 till date, there has been a drastic decrease in rainfall in South Africa leading to increased heat. Food production in Southern Africa depends solely on climate variabilities, this explains that South Africa depends on the timing and amount of rainfall and availability of water for irrigation in the country (The fourth assessment report of the intergovernmental panel on climate change IPCC, 2007).

Agricultural sector in South Africa has been known to play an important role in contributing to the growth of the economy of the country. Because of this dependence, it has been proven by research findings that the country's gross domestic product (GDP) could fall by 1.5% by 2050 (IPCC,

2012). This fall amounts to its total annual foreign direct investment, and this shows that climate change impacts other economic sectors which are directly or indirectly dependent on the agricultural sector in the country more especially the sector which export primary commodities (IPCC, 2012). It is therefore important for the country to have a viable agricultural industry to help contribute to the country's GDP, food security, social welfare, job creation and ecotourism while adding value to raw materials. Profitable yields, well-being of farmers and farm workers must be ensured by using proper farm management practices and ensuring long-term productivity.

However, despite several mitigation actions that has been put in place to combat this menace in the last few decades, further climate changes cannot be avoided due to the high concentration of greenhouse gases (GHGs) in the atmosphere (Nhemachena, 2014) and mitigation efforts do take time. It is therefore important to put in place several adaptation measures because it helps to manage climate change impacts in the long term and are felt at the local community level (farm level). This is of high importance in developing countries particularly in Africa, which are more vulnerable to these impacts. It is therefore important to help farmers recognize ways to strengthen their adaptive capabilities so as to help fight against climate change impacts in their communities especially at the farm level. It is very key to have a better understanding of the adaptation actions that has been used by the farmers and their determinant factors which influence their decisions to adapt or not to climate change impacts in their communities., This will help improve the policy planning that can be put in place to fight against climate change impacts.

1.2 The Research Problem

The debate on the impacts of changes in climate on the livelihood of people and the need to act has been overstretched and since has shifted to the development of adaptation options needed by different regions and countries especially among crop farmers to adapt to climate change effects. Climate change has a potentially strong impact on agricultural production, use of land, aquaculture, energy and biodiversity, health and water resources most especially in South Africa and all Sub-Saharan African countries (IPCC, 2007). Changes in climate have impact on agricultural production in diverse ways which includes changes in average temperature, rainfall, and climatic

extremes such as floods and droughts, changes in pests and diseases, changes in the nutritional quality of foods and changes in sea level (IPCC, 2012). Food insecurity risks are prone to increase in the country due to these changes and these could also lead to harsh impairment of crop production if no adaptation actions are taken, both large-scale and small-holder farming will be affected (World Bank, 2010).

Agriculture in Limpopo Province is largely dependent on climatic conditions (rainfall and temperature), this makes it vulnerable to the impacts of changes in climate. According to (Tshiala et al. 2010), changes in climate has impacted Limpopo Province negatively and has led to poor economic development in the community. Therefore, effective adaptation measures should be put in place and implemented by the farmers so that they can contribute to the development of the province and also help the government achieve its objectives through policy decision making process and to understand the determinant factors that influence the farmers' decision and choices in adopting these measures. The rural communities of Limpopo places great emphasis on the production of maize, vegetables, tomatoes and avocado which has been affected by these changes (Mpandeli et al. 2005). Makhura, (2001) explained that women are more affected by this menace more than men as women take up the responsibility of fending for their families. To approach this issue appropriately, understanding of climate change by the local communities must be put into consideration as some of them strongly believe that climate change is connected to spiritual, physical and emotional dimension. It is therefore assumed that these communities have the ability to adapt to these changes naturally to help them cope with the impacts of changes in climate and understand how they respond to these effects so as to sustain their production and availability of food. Therefore, proper understanding of these adaptation strategies and coping mechanisms are important in order to be able to take necessary actions needed to mitigate these changes in climate.

Many studies have been done on farm level adaptation measures especially in the rainforest region of Africa (Tanyi *et al*., 2018; Owoeye, 2020). Also, many attempts have been made to study the strategies and determinants for adapting to climate change (Kam et al. 2010, Adebayo, 2012, Ozor et al. 2010). But few of these studies have been carried out in Limpopo Province, South Africa.

however, this research looked further into the climate change adaptation measures that were adopted by the farmers in the study area and the determinant factors that influence their use of these strategies so as to provide better support capabilities for them and to enhance the use and adoption of more adaptation measures in the agricultural sector. This process can potentially assist in reducing the great widespread of the negative effects of changes in climatic conditions on agricultural production. Still, little is known regarding the farmers' adaptation options, the constraints faced by them, determinant factors affecting the use of climate change adaptation measures and the impacts of climate change on crop production systems in Limpopo Province, South Africa. Most researches have focused on regional and national assessments of impacts of climate change adaptation, (The Department of International Development DFID, 2009) but do not take into account the understanding of the determinant factors of adaptation options especially at the farm-level which if done, may provide more policy insights in identifying the variables that enhance the use of adaptation measures in agriculture. This has left a void in research.

This research intends to identify how climate change has affected the farmers in the Limpopo province especially at the farm level by considering the determinants of the communities' adaptation to changes in climate. This is important because agricultural production is sustained through the actions that these crop farmers take and their ability to make decisions depends on the level of knowledge and information available to them.

1.3 Research Questions

To fill the identified empirical gap, this study examines the impact of climate change and its variability on crop production and the determinant factors that affects the use of various adaptation measures to cope with the negative impact of climate change in Limpopo Province, South Africa.

The study therefore seeks to provide answers to the following research questions:

1. What are the socio-economic characteristics of the respondents (crop farmers) in the study area?
2. What are the factors that influence crop farmers' decision to adapt or not to climate change in study area?

3. What are the farmers' perceptions towards climate change?
4. What are the adaptation measures to be taken into consideration and where they can be prioritized to reduce climate change and variability on agricultural productivity in the study area?

1.4 The Aim and Objectives of the Study

The aim of this study is to determine the factors that influence avocado and tomato small scale farmers' climate change adaptation decisions in Limpopo province of South Africa.

The specific objectives are to:

1. To determine the socio-economic characteristics of the respondents (crop farmers) in the study area
2. To identify the factors influencing the farmer's decision to adapt to the negative impacts of climate change
3. To assess the farmers' perceptions towards climate change
4. To assess the specific climate change adaptation strategies the farmers have adopted to help cope with the negative impacts of climate change

1.5 Justification of the Study

Farmers in South Africa has been proven to have been fighting against climate change and its variabilities for the past decades because this affects their means of livelihood and it is evident in communities where agricultural production activities are mainly done. Due to these increasing risks of changes in climate, both socio-economic and ecological systems are affected (Adger et al. 2003). Due to this problem coupled with other non-climate factors, farmers are being put under pressure to make decisions so as to use one or more adaptation measures in order to boost their crop production and increase their commercialization. This study explores and brings out key details regarding the factors that influence farmers' decisions to adopt climate change adaptations and the impact of this action on crop production among smallholder crop farmers thereby justifying the need for critical thoughts on the consideration of crop farmers in the scheme of things in the policy making arena.

1.6 Limitations of the Study

This research study was limited to some specific areas and points. The questionnaires used for data retrieval were written in English and most of the farmers in the study area do not understand English. Therefore, the questionnaire was translated to the local language with the help of a translator so that the respondents are able to answer the questions and fill the questionnaires. Another challenge leading to limitation of the study is that some of the farmers could not provide accurate answers to questions regarding climate change observation over the years and their yield outcome and this was solved by getting the data from the South African weather services.

1.7 Organization of the Thesis

The chapters in the dissertation are organized as follows:

Chapter 1 provides the background to the study, the problem statement, the aims and objectives of the study, justification of the study and the limitations that the study encountered.

Chapter 2 focuses on the literature review of the impacts of climate change on agricultural productivity across the globe, in Africa, South Africa and also in the study area (Limpopo province of South Africa). This chapter also provides an overview of the awareness and perception of the farmers on climate change impacts, the adaptation strategies that were adopted by these farmers to cope with its impacts and the determinant factors of the farmers' adaptation measures to climate variabilities and change.

Chapter 3 provides a brief description of the study area, the research methodology used, the sampling and data collection methods that was used for the purpose of the study and the econometric models that were also used.

Chapter 4 gives the detailed explanation of the socio-economic characteristics of the respondents in the study area using descriptive statistics and discussions of the inferential analysis that was used for the study.

Chapter 5 presents the summary, conclusions and recommendations based on the findings of the study.

This chapter gives a brief introduction on climate change which is a major ecological matter affecting the globe at large. The next chapter presents a detailed insight about climate change and how it is affecting the Agricultural sector of South Africa and the whole world at large.

CHAPTER 2

2.1 LITERATURE REVIEW

Climate in the simple term means the prevailing weather condition of a particular place over a long period of time. This can be different from one region to another. Changes in weather can happen for a particular place at the same time for example a place can be wet and cool in the cold season and at the same time can be warm and dry in the summer. Climate of different places cannot be the same. Weather is different from climate in that weather is the state of the atmosphere of a particular place at a particular time. Changes in weather happens at different places at the same given time. People in a particular place can be feeling hot at a particular season while other people far away from that place might be feeling cold and shoveling snow at the same time, this literally means that climate is different from weather.

2.1.1 Definition of climate change

Climate change can be defined as the adjustments that occur in the weather of a place over a long period of time. These changes occur in climate conditions across the world or geographically and they occur in weather phenomena including temperature and sea levels. They are caused by the deposition of greenhouse gases which are mostly fossil fuel emissions in the atmosphere. These gases are trapped in the atmosphere thereby causing changes in weather pattern, this leads to global warming. United States Environmental Protection Agency (USEPA), 2014 described these changes in climate as the variations that occur in weather events such as rain, temperature and wind over a long period of time.

Intergovernmental Panel on Climate Change (IPCC) gave their own definition of climate change as the process where there are variations in the state of climate, these variations are visible in the mean and variability of climate properties which are persistent over a long period of time typically for decades. According to science and technology, climate change started in the industrial revolution and continued into the 20^{th} century when fossil fuel burning (hydrocarbon deposits such as coal, natural gas, petroleum) were at a very high rate. Steam engines, large industrial machines and other mechanical products were largely operated by using the burning of fossil fuel and this

has been going on for the last couple of hundreds of years. Carbon emissions has gone over the edge in the last couple of years due to the constant use of vehicles and planes. Agricultural activities are also not left out of these problems as land clearing for both agricultural use and urban development has led to depletion of the lifespan of plants across the globe and increased production of carbon emissions. All these results to changes in climate.

Glaciers are melting as a result of rise in temperature, sea levels are rising, animals are being affected either by diminishing natural habitats or through chemical changes that is occurring in their environment. Occurrence of severe weather events such as flooding, hurricanes and storm has been ongoing across the globe due to the changes in the earth's temperature and all these events also affects crop production. When there is extreme heat which is as a result of changes in climate, both plants and animals are also affected thereby making their habitats unlivable for them. Many research findings have proved the establishment of the impacts of changes in climate in Africa. Impacts of climate change on agriculture was studied in eleven African countries by Hassan, (2010) using the Ricardian method and the study concluded that crop production under irrigation in the warmer areas benefited more than crop production that was carried out in warmer areas without irrigation.

2.2 Impacts of Climate Change on Agricultural Production across countries in the World

Evidences has been presented all over the world that changes in climate which were observed in the recent times have already affected a variety of physical and biological systems and most of these effects have been attributed to global earth warming. It has been seen to be one of the most important hazards influencing the world's environment in the recent times. Climate change is already threatening food systems and rural livelihoods across the world. Agricultural production and livelihood of the people are already detrimental to the effects of changes in climate and these has made people susceptible to a lot of risks across the globe due to these occurrences such as droughts, floods, ocean acidification and hurricanes. Farming and people's livelihood are threatened by these events and these put our crops and livestock, fish resources and irrigation systems at high risks (FAO, 2016).

Climate change in Australia has been a critical issue since the beginning of the 21st century. The report from state of the climate in 2018 explained that warming in Australia has increased by 1^0C since the year 1910 and this has led to the occurrence of extreme events. Oceans are being warmed up and this has led to constant occurrence of marine heatwaves and rising sea levels. rainfall has decreased by approximately 10-20% since the 1970s across the various regions in the country, these changes have also made heat waves occurrence to increase. Fire weather and frequent unavailability of water as such has affected their agricultural productivity.

Sandeep et al. (2018) explained in their research that Srivasta et al. (2010) reported the impacts changes in climate has on sorghum production in India. The findings explained that there will be a decrease in the yields of sorghum by 7% by 2020, by 11% by 2050 and it will further reduce by 32% by 2080. This decrease in yield will be as a result of increased heat events and diminishing growth of the crops from impacts of changes in climate. This has proven that sorghum productivity in India is very low compared to the global average.

Over the past two decades, Sri Lanka has experienced significant climate change (Meniker et al. 2016). Extreme events like floods, droughts/ prolonged dry seasons and winds were accounted to have increased in the last 20 years. All these has been a threat to the agricultural sector which contributes 10.9% to the GDP of the country as 77.4% of its population live in the rural areas where majority of farming activities takes place. This has made them more vulnerable to food insecurity and unemployment as 31% of the population are gainfully employed in the farming system.

Agriculture is an important sector of the United State of America's economy which are highly dependent on the impact of climate change including fisheries. Crops, livestock and seafood produced in the U.S.A contributes more than 330 billion dollars to the economy each year. When there is temperature and carbon dioxide increase, it can lead to increased crop yield for some crops in some places but detrimental to another. Changes in frequency and severity of droughts and floods pose challenges for farmers and livestock producers and this in turn threatens food safety

in the country (United State of America global change governmental report, 2014). The 2014 reports also explained that climate disruptions to agricultural production in the U.S has increased in the past 40 years and are projected to increase over the next 25 years which will be increasingly having negative impacts on most crops and livestock. It was projected that by Mid-century, temperature in the U.S will increase to between 1.8 °Ft- 5.4 °F; and decline in rainfall will be intensified, thereby leading to major decline in crops and farm profits.

Corn yields between 2010-2012 was greatly affected by the increase in temperature across the corn belts. The temperature was seen to have increased by as much as 30% thereby making yield reduction more prevalent. Exposure to hot nights has increased the degree of stress imposed on animals resulting in reduced rate of meat, milk and egg production (U.S global change governmental report, 2014). Tubiello (2002) projected in their climate research report that between the year 2030-2090, there will be reduction in precipitation in some rain-fed production areas which will lead to decrease in crop yields in the country by 30-40% in crops like wheat, maize, potatoes and citrus.

2.3 Impacts of Climate Change on Agricultural Production in Africa

Agriculture and food security in Africa have been under threats due to changes in climate and its impacts are evident across the globe. Yields from crops and its quality are affected, livestock health, agricultural practices as well as pest control and also the different crops and animals that could be raised in particular climatic areas are also affected.

Global warming is increasing and its temperature is seen to be increasing sporadically. Global warming has been on the increase, it was recorded that it has increased in the last 50 years and has doubled what it has always been in the last 100 years and has even gone much higher in the last 25 years (Trenberth *et al.*, 2007). Rising of the sea level also shows that the earth is warming. Past findings show that intense heat globally may be beneficial to Agricultural production in the temperate region and lead to reduced crop yields in the tropical region across the globe (United Nations Environment Program (UNEP), 2009). These findings are also supported by World trade

organization and the United Nations report which explained that African countries are more susceptible to floods, drought occurrence and many other weather events in the future. Intergovernmental panel on climate change report, (2007) shows that there will be temperature rise of about 3-4^{0}C between the year 1980-2099 across the African continent, this variation is about 1.5 times higher than the global level and is even expected to be higher than that in some other part of the world.

Agriculture is more sensitive to the impacts of climate change. This is so because it is more dependent on natural resources which are more climate sensitive (Howden et al. 2007). It is affected by the variations in temperature, rainfall and carbon dioxide deposits in the atmosphere. These changes also directly affect crop and livestock production which leads to low yield and increased infestation of pests and diseases. Farmers face a lot of challenges concerning tragic low crop yield and incidence of pests and diseases due to changes in climate. World Bank, (2015) also reported that about 70% of the population in developing countries live in the rural areas and their main support of livelihood is Agriculture. This shows that Africa's economy is largely dominated by Agriculture and contribute about 40% to its GDP. Agriculture also contributes about 28% to South Asia's GDP.

Plant growth and yield are both affected by changes in climate either in the positive way or in the negative way and these effects are caused by rise in carbon dioxide concentration, higher heat occurrence and change in rainfall pattern, variations in availability of water and increased weather extremes such as droughts, soil erosion, heavy rainfall, floods and other changes. The Warsaw international mechanism for loss and damage associated with climate change impacts, formed in 2013, has also showed concern on the issues facing developing countries which is arising from the impacts of changes in climate and its adverse effects on Agricultural productivity. This body promotes the implementation of the approaches to be taken to address the loss and damage done to African countries in a comprehensive, integrated and coherent manner.

Past studies show that food production and crop yield declined drastically by 24% in Ethiopia between 1997-1998 due to low rainfall in which the farmers were unable to prepare their land for

planting, there was dry spells in the peak rainfall season, June-September and these has severely affected the growth stage of their crops (Desalegn, 2014). It is also reported that in Kenya, there was heavy rainfall between 1997-1998 which had severe impacts negatively on agricultural activities within the country. It was revealed that there was a wide spread of flood within the country which led to loss of properties and erosion of the soil increased in areas where their farmlands were not managed and used properly, increased frequency of mud and landslides and surface and groundwater pollution. All these affected their productivity in that; increased rate of rainfall led to increased plant and animal diseases which affected their livestock and crop production, soil erosion which led to surface run-off of soil nutrients thereby making farming lands not suitable for planting, several farms were water-logged leading to reduced crop yields.

However, this report showed that in the arid and semi-arid areas of the country, the rain was a big relief from the heat wave they were facing, leading to growth of good pasture for livestock performance and increase in agricultural production due to availability of moisture for the crop. Tree planting and survival rates were generally increased to nearly 100%.

Due to changes in Kenya's weather pattern over the past years 2001 - 2011, Mwendwa et al. (2012) reported that agriculture contributes about 25% to their GDP and generates 60% of their foreign exchange earnings. The disparities in rainfall pattern and distribution have affected the country in that they do not have enough ability to provide food for themselves especially when their farming activities rely solely on rainfall for water availability. They are therefore exposed to food insecurities, water scarcity, low yields and high poverty level. Vulnerability to climate change effects is evident in developing countries because they lack resources needed to adapt to the social norms, advanced technology and financial stability (United Nations Framework Convention on Climate Change (UNFCCC), 2007). This means that developing countries are not able to meet the sustainable development goals highlighted by the United Nations to be achieved by 2015 due to their vulnerability to changes in climate (UNFCCC, 2007).

Intergovernmental panel on climate change (2007) report also showed that different countries in Africa are also facing steppe climate which is making agricultural production activities difficult to carry out and this will reduce the time of planting and also force countries that take part wholly in agriculture out of production. Crop yield could reduce as much as 50% by 2020 in some countries and income from crops could fall by 90% by 2100, this will mostly affect the small-scale farmers. This in turn could adversely affect food production and food security in Africa.

2.4 Impacts of Climate Change on Agricultural Production in South Africa

It has been reported by the United Nations Development Program (UNDP) (2007) that Sub-Saharan Africa is mostly vulnerable to the adverse effects of changes in climate. Fourth Assessment report of the Intergovernmental panel on Climate change (IPCC, 2007) also stated that food production in Southern Africa is dependent on the amount and timing of rainfall and whether if water is available for irrigation systems. Eradicating food insecurity and poverty in Africa is one of the main goals on Sustainable development (SDGs) that United Nations are focused on and despite their doings and efforts, 815 million people are still faced with high poverty rate and food insecurity and nearly two-thirds of whom are in the Sub-Saharan Africa and South Asia (Niles and Salemo, 2018). Most of these population are basically small holder farmers and livestock keepers. Food insecurity will continue to increase due to the effects of these climate change, its variabilities and extreme weather conditions will continue to grow which will in turn affect Agriculture in diverse ways.

Farmers are showing major concern about climate change in South Africa, this was explained in the research findings by Ziervogel et al. (2014). It was also reported by Benhin (2006) using data from 1981 to 2003 that the annual average temperature in South Africa has increased by 0.13 degree Celsius. Academy of science for South Africa also reported that South Africa has been approximately 2% hotter and at least 6% drier over the years between the period of 1997-2006 compared to the 1970s. Water usage has also increased over that same period. It also stated that by year 2000, 98.6% of that year's surface water yield and 41% of the annual utilizable potential

of ground water was allocated to use. Water is being greatly consumed by irrigation agriculture in the country which has amounted to 60% of total water consumption.

This explains the nation's sensitivity to changes in climate. It is affecting agricultural production and the growth and reproduction of plant pathogens which reduces crop yield and quality. The average annual rainfall in the country has fallen to 450 mm/year which is below 860 mm/year (world's average). It is also reported that evapo-transpiration has increased in the country to 1500 mm/year resulting in only 8.5% run-off of the continent, with the average for the whole continent of 139 mm/year and the world average of 330 mm/year. It is seen that the surface run-off in South Africa is very low and also varies from region to region and from year to year (Department of Water Affairs and Forestry (DWAF), 2002).

Climate change have posed a lot of negative impacts on production agriculture, land use for agriculture, horticulture and forestry and it is important that farmers understand these effects so as to know how they can tackle them. 20-25 % of harvested crops worldwide are lost to pre-harvest and post-harvest diseases and if proper adaptation or mitigation measures are not taken, these losses tend to increase (Geoffrey, 2012). Pathogens capable of destroying crops and harvested produce have become more active and damaging because their lifespan are expanding as a consequence of climate change. He also explained that most degraded land which has amounted to about 40% of the world's arable land are situated in the poorer nations where rain-fed farming is practiced. These areas have been overgrazed, deforested and lands are inappropriately used. About an extra 11% of land in Southern Africa could suffer severe constraints to cropping, explaining that by 2080, there would be decrease in potentially good agricultural land.

2.5 Impacts of Climate Change on Agricultural Production in The Limpopo Province of South Africa

Limpopo is one of the nine provinces in South Africa. It is known to be rich in agricultural land area. Most vegetables and fruits are produced in this province such as avocado, maize, mangoes, pawpaw, groundnuts, litchis, tomatoes, cotton and potatoes with citrus and tea plantations prevalent in the central and northern areas (Statistics, South Africa (STATS S.A), 2014).

Major Agricultural activities are seen to take place in the Limpopo Province of South Africa, and it is regarded as the country's breadbasket and also a significant producer of livestock (STATS S.A, 2014). Seventy percent of its agricultural land are cultivated by large-scale farmers who amounted to about 5000 in number (KPMG report, 2012) and about 303,000 small holder farmers are cultivating on the remaining 30% of the agricultural land. Majority of these small holder farmers do not make use of new and improved technology techniques on their farms and despite this, the agricultural sector contributed 3% to the province's annual average GDP in 2012. Rural smallholder farmers in the region depends heavily on natural resources and are prone to environmental, economic and social impacts caused by climate change and land use intensification (De Kock and Pillay, 2012).

Adaptation to climate change and variability has been a major challenge for successful farming in the province (Conway et al., 2015). Tomato crop farmers are known to be facing these challenges as there was fluctuation (increase and decrease) in their productivity over a period of years (Tshiala and Olwoch. 2010), this is because tomato crops have high sensitivity to the impacts of climate change and its variabilities. This was due to the occurrence of droughts experienced in some parts of the province. Farmers are therefore facing a lot of possible negative impacts on crop yields in the region, especially farmers without improved technology and good modern agricultural practices. Because of this, there is less food available to households which in turn is linked to the fact that there is poor health within the society. This has a direct proportion (drought) to climate, water and economic stress and people are moving away from agricultural activities to non-farm activities to earn a living so as to reduce these stresses.

2.6 Climate Change Modelling in South Africa

Agriculture is the main backbone of economy in rural communities in Africa, its importance cannot be over emphasized in South Africa in relation to food security. Because of this, understanding climate change and climate variabilities and its impacts in respect to Agriculture in South Africa is of utmost importance and a variety of modelling approach has been used to tackle these problems.

Decision Support System for Agro-technology Transfer (DSSAT) and Agricultural Production System Simulator (APSIM) are examples of models that has been used in the past. Another model is the Climate envelope distribution modelling which is used to estimate changes in crops or identify lands that are suitable for forest plantation. This distribution model has been used by researchers in the past to understand the effects of changes in climate variabilities on crops and livestock sectors, changes in pest and disease distribution. Observed empirical relationships between abiotic variables such as climate and current distribution or crop presence points are used to determine areas that will fall under future climate. DSSAT is a crop simulation model that has been used at different spatial and temporal scales, this includes, understanding on-farm and precision management, geographical assessments of the impacts of climate variability and changes in climate, water use and greenhouse gas emissions (Hoogenboom et al. DSSAT, 2019). However, the new DSSAT model has been improved on and this helps to assess the investments that has been affected by macroeconomic conditions and environmental impacts associated with irrigation system, fertilizer application and nutrient management, climate variability, soil carbon sequestration and precision management.

Singels et al. (2018) performed research in South Africa on sugarcane productivity and water use under a future climate using the DSSAT- model. Results from this research shows that temperature are expected to increase by about 2degree Celsius in the nearest future and rainfall to increase slightly annually especially in the northern part of the country. Because of the slight increase in rainfall, it was projected that there will be increase in dryland yield between 11-33% in warm and cool areas and due to the increase in temperature, crop water use and irrigation requirement are expected to increase by between 8-11%, respectively. These results have made areas in the Limpopo (Northern part), Eastern Cape (North eastern part), Mpumalanga and KwaZulu-Natal to be projected to be suitable for sugarcane production in South Africa. APSIM model was developed to assume natural environment in agricultural systems. Solutions are been proffered by past researchers to issues related to food security problems, climate change adaptation and mitigation measures with the use of APSIM model. It provides an accurate prediction of agricultural

production in relation to climate variations, genotype and soil management factor which also solves the long-term resource management issues (Holzworth et al. 2014).

2.7 Environmental Problems Associated with Climate Change

2.7.1 Deforestation

This involves cutting down of trees on a large-scale in the forests, burning of living and dead vegetation with the use of natural or lightning-induced fires. Over the time, this has led to the degradation of forests in Africa and have contributed immensely to changes in climate. Thousands of different species of plants and animals are going into extinction in Africa because of the depletion of forests and other habitats (Alima 2015). Most natural resources are gotten from the forests and this adds value both economically and ecologically to its habitats and serve as a home to about 90% of the world's terrestrial biodiversity and also as a means of survival for over 1 billion of the world's poorest people, providing raw materials for food, shelter and fuel (WWF, 2011).

Deforestation and forest depletion cause about one-fifth of global greenhouse gas emissions, this shows that forest is an important factor to be considered in the fight against changes in climate. A lot has been done to help reduce emissions from deforestation and forest degradation and forests has helped to contribute to this environmental service by helping to put in place certain policies that can be adopted by the farmers to help reduce these emissions and also create financial means to the farmers (REDD+).

Habitat destruction, biodiversity loss and aridity occur because trees are removed usually through deforestation and these trees are not planted back either naturally or by intentional restocking (reforestation). Soil erosion usually occur on deforested land areas which make them not useful and turn into a wasteland. It was established according to the United Nations Framework convention on climate change (UNFCCC) secretariat, that "Agriculture" is mainly responsible for deforestation. Subsistence farming account for about 48% of cutting of trees in the forest while commercial farming is responsible for 32% deforestation. Logging (cutting, skidding, on-site processing, and loading of trees onto trucks) is responsible for 14% and fuelwood removal makeup

the remaining 6%. However, these are not the only causes of deforestation, other studies show that some other factors are responsible for deforestation such as uneven equality in the distribution of wealth and power, over population, urbanization and globalization (WWF, 2011). Deforestation is seen to be a major dominator to global warming (Food and Agricultural Organization 2015).

2.7.2 Irrigation

This involves the supply of water at needed intervals to lands and crops to help growth, typically by means of channels. Irrigation helps to grow agricultural crops, maintain landscapes and enrich distressed soils in arid areas. Environmental impact of irrigation relates to the changes in the quality and quantity of soil and water. A direct impact of this is altered by hydrological conditions. This occurs when an irrigation system is been put in place to draw water from lakes, riverbank, groundwater or over the land flow and it is been administered over an area. Because of this process, the river flow is reduced which leads to increased evaporation in the irrigated area, the water table of the irrigated area is increased. Its impact is the immediate provision of moisture to the atmosphere, including atmospheric stabilities thereby increasing downwind rainfall (Lo and Famiglietti 2012).

Irrigation also has direct effects on the environment. these effects take longer time to develop and are hazardous. They include: water logging, and soil salination which occurs that is, saturation of the soil with water, soils are not suitable for planting therefore, there is reduced agricultural production. When water tables are low, application of irrigation systems on the farm are reduced thereby soil leaching no longer occurs and soil salinity problems develops. When there are non-flowing water tables, which is at the surface of the soil, water- borne disease incidences increases such as malaria, yellow fever and filariasis. This makes the people living within this area vulnerable to constant health problems. However, there has been a lot of ways to mitigate the adverse effects of irrigation both on ecology and socioeconomic. These includes siting irrigation projects in areas or location that minimizes its negative impacts, developing minor, personally owned irrigation schemes as an alternative to large, publicly owned irrigation system and also the use of sprinkler and micro-irrigation systems which helps to reduce the risk of erosion happening and water logging (FAO, 2014).

2.7.3 Pollutants

Agricultural pollution refers to the decomposition of plants and animal byproducts, non-living and chemical factors affecting the environment (biotic and abiotic byproducts) which results in defilement or degradation of the environment and ecosystem that surrounds it. This causes damage to humans and their economic interests. Management practices are also known to play an important role in the amount and impact of these pollutants in the environment.

Abiotic sources refer to pesticides and herbicides. They are applied to cultivated lands to control incidence of pests and weeds that disrupts crop production. When these pesticides accumulate in the soil, soil contamination can occur thereby making the microbial process in the soil to be disturbed, the plants absorb these chemicals and causes damage to them and toxicity to the soil organisms.

Pesticides also mixes with water, move through the soil and contaminates the groundwater, this process is called "Pesticide Leaching" and it often occurs when water soluble pesticides are used. Also, when fertilizers such as nitrogen-containing fertilizers are applied in heavy quantity together with the high water- soluble nitrates, water surface runoff is increased, leaching also occurs and this leads to pollution.

2.8 Understanding Climate Variability and Change; The Major Cause and Effects

Variations occur in climate in the short terms either daily, annual, seasonal or several years, this term is called "Climate variability". It also includes the fluctuations that occur with El Nino (dry) and La Nina (wet) events. This definition was given by the South Eastern Australian Climate Initiative. Gan et al. (2016) stated that Africa is the hottest continent and it constitute about 60% of deserts and dryland. They explained that total of twelve drought occurrence has happened in East Africa over the last fifteen years and sixteen droughts were identified at the national level and warnings were issued between 1960- 2011. The study also showed that environmental damage which is caused by drought has been on the high side in Africa, these damages include high poverty level index, crop production failure and humanitarian crises. Intergovernmental panel on climate

change (2012), also stated that there has been an increase in the occurrence of natural disasters such as floods and droughts since the year 1970 and these has contributed immensely to the impacts of changes in climate and its variabilities. Kulyakwave et al. (2019) research stated that farmers in Tanzania agreed that receiving less rainfall than their previous season was an indicator that weather has changed. It pointed out that, dryness of tender tree leaves is an indicator for weather fluctuations particularly lack of rainfall and increase in sun intensity.

2.8.1 Causes of Climate Variabilities

There are many causes leading to changes in climate to mention a few;

1. Natural climate variations
2. Human-induced climate variations (effects of GHG emissions)

Natural climate variations can further be divided into;

1. Natural forcing of the climate system
2. The sun and the global energy balance
3. Radiative forcing and green-house effects

Natural climate variabilities refer to the variations in climate parameters caused by non-human forces. Changes that occur over a long period of time is caused by variations in the sun, volcanic eruptions and change in the orbital of the earth and the sun. The sun is the ultimate source of energy in the climate system and cyclical changes in its output occurs. These changes cause variations in climate over the past years. However, International panel on climate change (2011), explained that it is not currently the dominant form of external climate variabilities.

2.9 Effects of Climate Variabilities on Agriculture and its Productivity

Crop production is influenced by climate variabilities, it affects all types of crops including year of crop production and agricultural areas that are high in technology (Kang et al. 2009). It affects agriculture in a process with no known end means. Southern-African region has been greatly affected by climate variabilities due to increasing rate of global warming. These has been evident through rainfall reduction, increased temperature leading to dryness and depletion in the amount of water available, plants and organism extinction (Obioha, 2010). His research explained that in

the year 2001 in Lesotho, widespread of frost and hailstorms in March severally affected crops in most districts, in late August, there was an unexpected heavy rainfall over most area in the country which resulted in very wet condition through October and December and in February 2002, it was generally dry throughout the country which affected food production and its activities. According to Food and Agricultural Organization (2006), between the year 2000-2006, there has been variations in the distribution of rainfall across Lesotho, which greatly affected their crop yield as most crop production is virtually rain-fed.

Rainfall pattern is changing in South Africa and this could lead to either drought occurrence or flooding across the country. It is also evident that temperature is rising which will cause planting season to change, wildfire and high incidence of pests and diseases (Chambwera and Stage 2010). However, Blignaut et al. (2009) explained that South Africa has gone hotter by almost 2% and dried by at 6% between the years 1997-2006. Results showed that the use of water was greatly increased over the years analyzing irrigation agriculture to about 60% use of the water allocated for consumption. It also explained that due to variations in climate, there was a decrease in the net agricultural income across the various provinces because to every 1% decline in rainfall that occurred, there was a 1.1% decrease in maize production (summer grain) and a 0.5% decrease in the production of wheat.

Tibig (2002) clarified that climate variabilities and change will seriously endanger sustained agricultural production through:

1. Moisture stress from prolonged dry spells
2. Increase in temperature (on crops and pathogens)
3. Thermal stress from heat wave occurrences
4. Stress in water availability

Physical and chemical properties of the atmosphere have severe anthropogenic effects on the quality of life and even the very existence of certain life forms. Intergovernmental panel on climate change (2001), reported that alterations in weather and climate results in high number of deaths, decrease in food production, water and land pollution, and destruction of basic infrastructures.

Climate variability which occurs at the local and regional level includes variations in the lengths of planting seasons, the availability of water, and the occurrence of weather extremes (extreme heat events, floods, droughts, fire outbreaks and pest infestations), these affects the formation and purpose of both natural and man-made environments.

Land degradation processes including floods, mass movements, soil erosion either by water or wind and salinization are happening across the world and this is as a result of increased incidents of climate events such as extreme high temperature events, droughts, heavy rainfall and so on (IPCC, 2007). Variability in climate, changes in climate and degradation of lands are linked together and their impacts on soils, water, forests and wetlands can be felt and seen. According to this report, variabilities in climate leads to decrease in availability of water for production and increased drought occurrence in both arid and semi-arid regions. As a result of this, a lot of people are exposed to the stress that comes with unavailability of water. Quality of water can also be seen to be affected by changes in temperature and weather extremes such as floods and droughts and these leads to different forms of water pollution. These pollutions range from dissolved organic carbon, pathogens, pesticides and salt deposits as well as heat pollution and they all have negative effects on ecosystems, human health, water reliability and operating costs.

2.10 Climate Change Awareness

It is important to examine whether farmers are aware and well informed about the impacts of climate change on their productivity, this is because changes in climate variabilities affect agricultural production and leads to low crop yield and livestock production, food insecurities, low income for famers and so on (Maponya et al. 2013). Subsistence farmers and the general population of any particular country decides on the strategies they want to adopt to help manage the impact of changes in climate and its variabilities which affects them and their agricultural production at large. These farmers however must be aware and well informed about climate change and its impacts before adopting any adaptation strategy. Several researches have been conducted across the world which serves the purpose of having a deep insight about how farmers are aware of climate change and its variabilities and how it has impacted agricultural production. Adebayo (2012) explained that small scale maize farmers with low or no resources in Nigeria are not well

informed and aware of climate change which in turn affects their choices of adopting adaptation strategies thereby affecting their productivity. This means that there is abrupt need for more awareness to be created amongst farmers on climate variability and change across the globe. More information needs to be passed across to them on how to tackle the impacts. Olayinka et al. (2013) reported that even though small-scale farmers stated that they know the climate is changing and are aware of its impacts, however they still have low knowledge about climate variability and change and its impacts on their production.

Francis et al. (2013) explained in his research that smallholder Cocoa farmers in Ghana are fully aware of climate change and its impact hence they have more knowledge on the coping mechanisms to adopt to help their Production. Kunene (2013) also stated in his findings that majority of the farmers who are aware of climate change in Eswatini had access to extension workers in their community to disseminate useful information about climate change to them hence take necessary actions to adapt to climate change impact. He further explained some factors that determine the farmer's choice of being aware of climate change; marital status, access to finance, access to extension services, age, farming experience and household size are factors that significantly determine whether the farmers are aware or not of climate change and its impacts in their community. He explained that older farmers can perceive the effects of changes in climate such changes in rainfall pattern and temperature. It is therefore important to raise awareness about climate change through all necessary available means of communication to the farmers which will in turn help them improve in making decisions about the adaptation measures they can adopt to help fight this menace. It is also important for governments, meteorological stations and agricultural departments and ministries to help contribute to this cause by raising awareness on the changes in climate conditions through all possible means of communication pathways available.

2.11 Perception of Farmers about Impacts of Climate Change and Its Variabilities

According to Oxford dictionary, "Perception" is defined as the way one notices things, especially with the senses, and be able to understand the true nature of it. A lot of studies on farmers' perception have identified certain limitations in their understanding of climate variability and

change (FAO, 2015). However, it is important for farmers to have a deep understanding of climate variabilities so as to be able to cope with it. This can be done in different ways at grass-root levels such as organizing trainings for them to enlighten them about climate variabilities, making them understand the importance of getting information from registered weather and climate information stations, and coming together to understand different crop varieties which can be planted at different planting seasons.

Debela et al. (2015) explained in their findings that farmers in South Ethiopia perceived changes in climate and its adverse impacts on their productivity and regard these changes as a risk to their future livelihood and economic development. They further explained some factors which obviously affected the perception of the farmers about climate change and these includes: age, level of education of the farmers, number of livestock owned by the farmer, access to information on climate change and extension services. Several researches have accessed the perception and level of awareness of small-scale crop farmers on the impacts and effects of climate variability and change on their production. Different inferential analysis has been done by these researchers to analyze small-scale farmers' perception across the Southern Africa and the globe as a whole. Kunene (2019) used the Principal Component Analysis (PCA) to examine the factors that influence the perceptions of small-scale maize farmers in eSwatini (Swaziland). His research discovered that most of the farmers in eSwatini perceived that climate change has a great impact on their maize production, shifts in rainfall has led to a great decrease in their crop yield while some perceived that there has been scarcity of water due to droughts and low rainfall. Musetha (2016) also explained in his research that farmers in the Limpopo province of South Africa perceive climate change in different ways and how they can adapt differently. They believed that temperature in the province is getting higher thereby making it hotter leading to shortage of water in the province. He also further explained that some farmers believe prayers can make the impacts of climate change to go away, some believe that by planting different crops on the farm can assist to adapt with climate change while some believes that crop diversification will also help them to cope with climate change impacts. Since agricultural production is being seen to play a major role in income contribution for rural communities (World Bank, 2013), it is important for those making policies

to understand how farmers perceive changes in climate which in turn helps them have a better way of making decisions relating to how climate variables are affecting the farmers' productivity and the agricultural community at large. When farmers are well aware of the changes in climate, it helps their decision making about adopting adaptation measures to help them cope with these changes and it is seen that size of farm and information received on climate change influences the farmers' awareness on climate change (Maponya and Mpandeli, 2012 as cited by Oduniyi, 2013 and Benhin, 2006). This indicates that farmers are able to deal properly with their production processes because they are aware of climate change and its variables that is changing in their community.

In addition, Trinh *et al*., (2018) stated that certain determinant factors such as the age of the head of the household, information on climate change, wealth, social capital and agroecological settings are directly related to farmers' perception on climate change and these in turn helps them to make proper decisions on the mitigating and adaptation measures they can use to cope with changes in climate. Information about weather, poverty and lack of knowledge on adaptation strategies has been seen to be the major factors that can affect farmers' decision making about climate change (Fosu- Mensah et al. 2012). Farmers particularly small-holder farmers are aware of changes in climate but do not have enough knowledge on how to tackle these problems. This is due to the fact that they do not have access to enough information either through different media forms or through extension services, this will in turn have a negative effect on their decision-making process.

Aphunu et al. (2012) stated that, even though farmers perceive that the climate is changing, they still do not have enough understanding of what is causing these changes and how they can tackle them. Most of the farmers relied upon their personal experiences on the farm to gather information about climate change. This makes awareness on climate change an important measure that needs to be taken serious by both the farmers and the government to help them fight against the impacts of climate change on agricultural productivity (Adebayo and Tukur 2003). Oduniyi (2013) also asserted that even though majority of the farmers understood what climate change is, they still do not have a deep understanding of what it is and how its variabilities are affecting their productivity.

2.12 Intention of Farmers to Adapt to Climate Change

"Intention" can be defined as something that you want and plan to do, your aim of doing something to achieve a result (Wang et al. 2016). Farmers' intention to adapt to climate change is a very important phase as this happens when they understand and perceive climate change and its variabilities. Luu et al. (2019) explained that farmers are willing to adopt some adaptation measures that will help them cope with climate change when the risks they have perceived is high. They know that if nothing is done to help fight this menace, a lot of things are at risk such as their physical health, their finances, productivity and their social relationships to mention a few. It was also reported in the research carried out in Vietnam that the intention of farmers increased when their style of production and behavior were oriented towards climate change adaptation. Elum et al. (2016) also stated that most farmers in South Africa have perceived climate change impacts and are taking up several adaptation strategies among which are, use of heat or drought-tolerant varieties and efficient irrigation system.

2.13 Agricultural Crop Production Adaptation Process to Climate Change

Smith and Skinner (2002) defined Adaptation as the "Adjustments in ecological social-economic systems in response to actual or expected climatic stimuli, their effects or impacts". Climatic variations affect agriculture in a process which have no limits, therefore Adaptation helps to reduce the adverse impacts and effects of climate change (Ghulam et al. 2017). The United Nations framework convention on climate change also defines Adaptation as "ways and means of reducing the impacts of, and vulnerabilities to climate change". Intergovernmental panel on climate change (2013), defined it as "the process of adjustment to actual or expected climate change and its effects".

The United Nations Framework Convention on Climate Change reported that in 2007, 187 countries showed the need for adaptation bills to be put in place hence, the adaptation fund under the Bali Action plan of the United Nations Framework Convention on Climate Change was established. Projects that help developing countries cope with these severe effects of changes in climate are being financed by this fund and is one of the only funds in the world specifically

dedicated to climate adaptation. Since 2010, the fund has approved 330 million dollars for a total of 57 adaptation initiatives around the world.

Farmers are being faced with a lot of challenges such as crop failures, low agricultural yield, damages to crops due to infestation of pests and diseases caused by impacts of climate change and these impacts can be mitigated or adapted to if proper mitigation and adaptation processes are adopted.

Ghulam et al. (2017) stated two ways by which impacts of changes in climate can be reduced; Mitigation and Adaptation. He further explains that Mitigation helps in the reduction process of the effects of greenhouse gas emissions or strengthen the evacuation of these gases from the atmosphere through carbon sinks which takes time. Hence, Adaptation is perceived to be critical and is perceived to be important especially in developing countries because they are highly vulnerable to climate change (Byanyima et al. 2016). Adverse effects of these changes are being seen to reduce through the application of these adaptation measures. However, past studies have said little about farm level adaptation strategies and its determinant factors. Ghulam et al. (2017) identified adaptation process in three steps; perception about climate change, intention to adapt and actual adaptation. This is seen in Figure1:

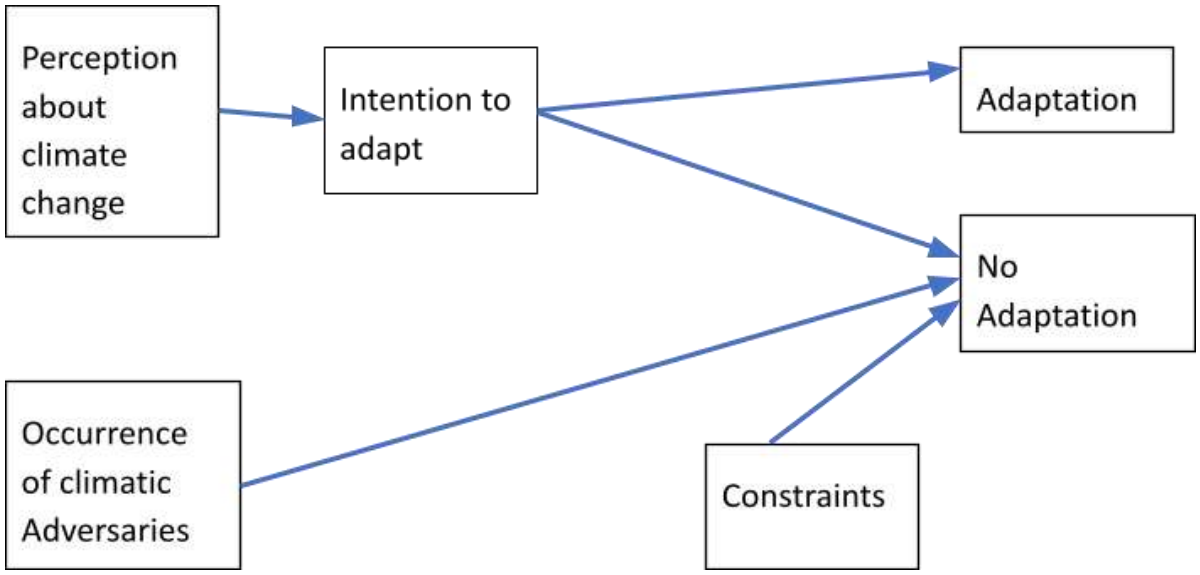

Figure 1.1: Adaptation Process (Source: Ghulam et al. 2017)

2.13.1 Actual Adaptation

An adaptation strategy can be described as well-planned actions that are used to help execute policies and measures. They are being put in place to deliver adaptations. Adaptation strategies need to be implemented at all times to reduce the impacts of changes in climate and its vulnerability. AEA Energy and Environment report to the European commission directorate general for Agriculture and rural development 2007, defined vulnerability to climate change as "the extent to which a system is susceptible to, or unable to cope with the adverse effects of climate change including climate variability and extremes". They described the various types of adaptation as follows:

1. Anticipatory and reactive adaptation
2. Private and public adaptation
3. Autonomous adaptation
4. Policy-driven (planned) Adaptation

Autonomous Adaptation is one that is brought about by ecological changes in natural systems or inhuman systems in response to changing conditions in their immediate environment. These strategies are taken by private sectors naturally such as individuals, households, businesses in response to actual or expected climate change and policy decisions does not intervene actively.

However, policy-driven adaptation is associated with public agencies. It occurs when policy making decisions are made intentionally (AEA Energy and Environment report, 2007).

Anticipatory Adaptation are known to be used before the impacts of climate change are observed (Michael et al. 2017). Intergovernmental panel on climate change (2007), defined vulnerability to climate change as the tendency that human and ecological systems have to suffer harm and the abilities they have to respond to these stresses that was forced on them as a result of impacts of changes in climate. Betzold and Weiler, 2018 explains that vulnerability has three components; exposure, sensitivity and adaptive capacity. These elements are interrelated and vary over time. This is shown in Figure 2.

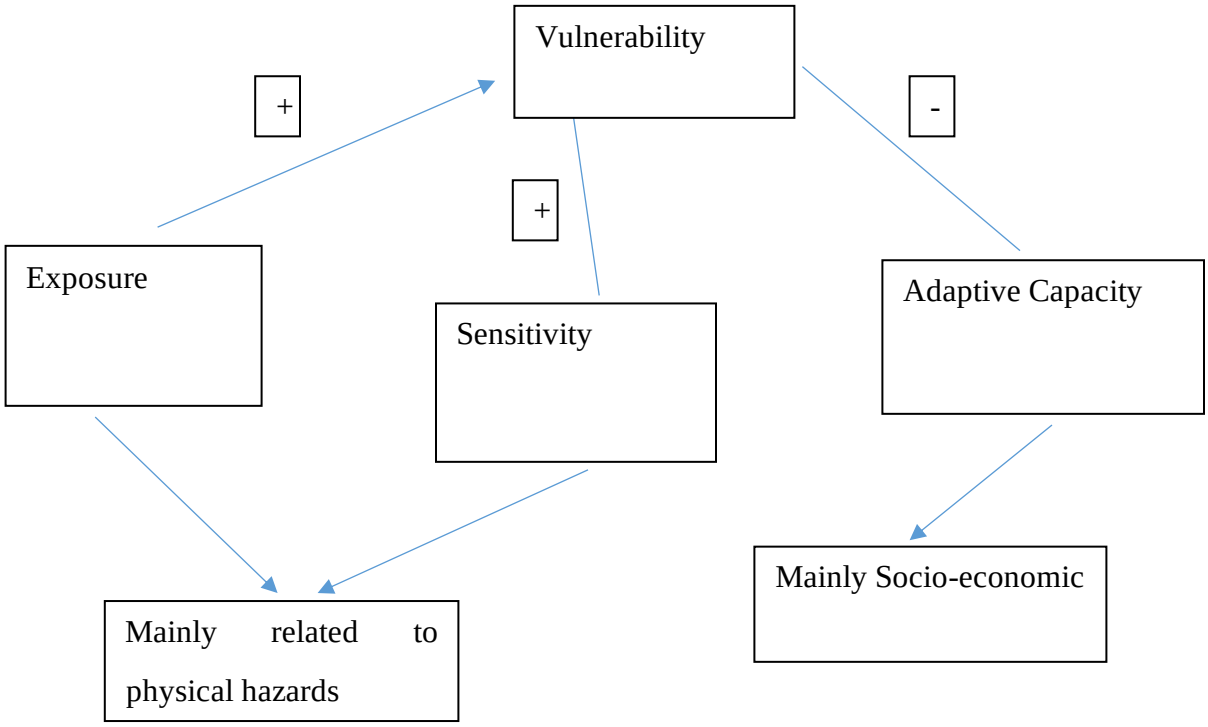

Figure 2.1: *Vulnerability and its components (Source: Betzold and Weiler, 2018)*

Intergovernmental panel on climate change, (2013) defines exposure as the presence of people in places or settings that are adversely affected by changes in climate. Other factors that can be exposed also includes: livelihoods, ecosystems, environmental functions, services and natural

resources, infrastructure or economic, social or cultural assets. It further explains sensitivity as the degree at which a system or species is affected by climate variability and change, this can be beneficial to the system or it can be adversely affected. Adaptive capacity can be defined as the ability of systems, institutions, humans and other organisms to adjust to potential damage to take advantage of opportunities or to respond to consequences (IPCC, 2013).

2.13.2 Enhancing Adaptive Capacity

Adaptation can be defined as the process whereby a system is adjusted to help reduce vulnerability and to increase the resilience of the system to change, this is also known as adaptive capacity. High adaptive capacity is known to be common amongst societies that responds fast and successfully to the impacts of climate change. However, having high adaptive capacity does not necessarily mean that the society will have a successful adaptation procedure. For example, there was a record of the bluetongue virus outbreak (livestock disease) in 2007 in Europe due to a rise in their warmer winter despite them having a high adaptive capacity. In a literature review, Smith et al. (2006) reported that activities that promote sustainable development are equal to having an enhanced adaptive capacity. These activities include:

- Improving access to resources
- Reduction in poverty rate
- Bringing inequalities of resources and wealth amongst groups to the minimum
- Boosting education and information systems
- Upgrading infrastructural facilities
- Refining institutional capacity and its efficiency
- Advancement in local indigenous practices, knowledge and experiences

2.14 Local Adaptation Efforts

A lot of responsibilities are being saddled to the government across the globe either at international, national, or regional level such as land use planning, public health, and natural disaster management. However, some countries have started to take decisions on how to adapt to these

threats that are posed by the changes in climate such as flooding, bushfires, heat waves, and rising sea levels.

Adaptation options practiced include:

- Information provision to farmers about changes in climate and its effects and adaptation efforts
- Establishment of geographical locations that will be available to farmers to get information about climate change and its variabilities and how they can cope with its impacts on their production
- Developing and installing new technologies and its materials that can stand against flooding
- Develop forecasts on agricultural pests and disease outbreaks
- Planting of varieties of trees that are tolerant and resistant to heat
- Storing rainwater as a means to deal with frequent flooding, adding water-shield vegetation, use of underground storage tanks, reducing the amount to purchase household rain barrels
- Change land management and land use pattern to reduce soil erosion
- Reduction in concrete areas to deal with rainwater and heat
- Inspect and understand local vulnerabilities, raise public awareness about it and design climate change specific planning tools such as future flood maps
- Design seed banks in such a way to ensure sustainability, have different varieties available, particularly when re-planting is necessary.

2.15 Climate Change Adaptation Strategies

Climate change mitigation and adaptation has been a major and intense menace been discussed about globally in the past few decades. Intergovernmental panel on climate change (2001) described mitigation strategies as the anthropogenic policies or interventions been put in place towards reducing GHG emissions. It is regarded as a long-term process in helping to solve or minimize the negative impacts of climate change in the nearest future. They also described

adaptation as the adjustments or moderations been put in place in natural or human systems in response to actual or expected climate change as well as taking advantages of new opportunities.

From these definitions, it can be rightfully said that adaptation helps manage climate change impacts in the short-run and hence makes it very important in fighting the impacts of climate of climate change especially in developing countries where vulnerability is high. Societies and ecosystem at large across the globe have been impacted by increased temperature, change in rainfall pattern and extreme weather events which will require direct and indirect measures to help adapt to these changes hence adaptation is extremely important. However, there has been a lot of societal responses to these climate change impacts across the globe. Farmers in China adopted buying weather index crop insurance which significantly has a positive effect on their level of adaptation (Jianjun et al. 2015), lying cities in the Netherland has built tall walls and buildings and also planned to move to other areas due to floods (Edelenbos et al. 2017) amongst others. Different literatures have identified several adaptation strategies used by people across the globe to cope or adapt to climate change impacts. (Kim et al. 2012) identified conventional coping strategies to not been effective at all times when used by people to help reduce climate change vulnerabilities within the ecosystem. An example is people who borrow money to repair their damaged houses or re-plant damaged crops in the same location in response to flood-related crisis. These coping mechanisms are not enough to protect these people or their communities from flood and its severe impacts.

This adaptation strategy can modify the social or ecological system to accommodate the changes but does not completely solve the problems of flooding in that particular area. Therefore, a more adaptive type of adaptation strategies is needed to help alter the characteristics of the social-ecological system. Fedele et al. (2019) grouped response to changes in climate into three categories: coping strategies, incremental adaptation and transformative adaptation.

***Coping strategies*:** These are strategies that people use to reduce the impacts from climate change and maintain the affected socio-ecological system. When the climate change impact is not intense,

people often make use of this type of adaptation strategy. It is also used when people do not have the financial capacity or technical know-how of how to combat climate change impact (Fedele et al. 2019). Example is farmers in Madagascar re-planting their damaged crops after occurrence of flood.

Incremental adaptation: These are strategies that provide significant benefits by accommodating the changes. It is more of anticipatory adaptation than coping strategies (Fedele et al. 2019). Examples are adjusting land management or agricultural practices to help combat climate change impacts such as use of irrigation system, increase the use of fertilizers and pesticides, change the amount of land cultivated amongst others.

***Transformative adaptation*:** Kates et al. (2012) defined "transformative adaptation" as the changes that can be put in place to fundamentally alter the socio- ecological system's properties so as to help solve or put to reduction the grassroot causes of the vulnerabilities to climate change such as social, economic, environmental and cultural related system been transformed into a more sustainable or resilient state. Example is changing from the use of fossil fuel to clean renewable energy production.

Farmers in different countries have however adopted different adaptation practices to cope with climate change impacts. These practices vary according to the climate region of each country. Farmers in Pakistan modifies agricultural and animal varieties and select more suitable ones for the new climate conditions. They make use of crop varieties that adapt more to their saline soil and still yield good results. Some changed their practices from agriculture to aquaculture to end transhumance. Some farmers make use of crop rotation to adapt, changed their input, made use of new technologies to understand climate change better. They also adapted with the use of Irrigation system on their farms, planting of trees and creation of shade areas on their farms to reduce climate change impact on their production level, building of more storage facilities were also encouraged to reduce food loss and enhance food security (Vermuelen et al. 2018). Unites States of America, Brazil and Argentina make use of biotechnology (genetically modified organisms) when planting

their crops in order to reduce the proliferation of bacteria and food deterioration that is associated with high temperature so as to increase their crop yield in order to meet the supply of food demand of the growing global population (IPCC, 2019).

Europe has undergone several actions to adapt to climate change in agriculture, water resources to mention a few. Croatia is known to have increased their level of awareness of climate variability and change as an adaptation strategy. Their water resources, agricultural and fishery sector has been affected by the impacts of climate change and a few adaptation actions has been taken to help cope with it. Rational use and measures of drinking water and irrigation system, building of urban drainage for storm water management to mention a few (Ronan and Bettina, 2019).

Small-scale coffee farmers in Central America have been affected by the impact of climate change (IPCC, 2019). This is evident in the increase in propagation area of coffee rust due to increased drought, which has subsequently led to poor coffee production in the country. However, a few adaptation actions have been adopted to fight these problems; some farmers have changed their production practices to the most suited ones that works with the climate at every point in time, changing the coffee production area to practice other agricultural production and non-agricultural diversification were considered. Loans and financial assistance were given to farmers to assist their production, and non-agricultural jobs were encouraged to help maintain their livelihood, more climate change services were provided to the farmers, such as how to eradicate agricultural pests, incentives to farmers, optimization of agronomic and marketing practices (Ronan and Bettina, 2019).

Osbahr et al. (2010) also identified that in India, farmers have adopted quite a number of adaptation strategies to help cope with climate change impacts especially in maize farming; use of ground water for irrigation, change in planting dates and harvesting, use of crop varieties that produce high yield, mixed-cropping, crop diversification, use of early matured cultivars and so on to mention a few. However, these adaptation strategies adopted are subject to different environmental factors (Gbetibouo et al. 2010). Sima et al. (2015) also Identify that the most important adaptation

strategy that farmers use to cope with the effect of climate change impact in Romania on their farms is the rehabilitation or construction of Irrigation systems.

2.16 Climate Adaptation Actions Across the Globe

Climate change is expected to worsen the problems that are already in existence and even create new ones especially in Africa. Many countries especially Sub-Saharan Africa are mostly exposed to the effects of changes in climate variations, due to the fact that they rely mostly on rain-fed agriculture for income and there is low adaptive capacity, unequal land distribution, limited access to capital and technology, inadequate public infrastructures and basic amenities such as roads, water and electricity, and so on to mention a few. Various adaptation strategies were adopted by farmers in different countries across Africa to help mitigate the impacts of changes in climate. Small scale farmers in Nigeria, Ghana, Burkina Faso and Senegal have over the time made use of planting drought-resistant crop varieties during hot seasons. Sudan, Tanzania and South Africa also adopted crop diversification to adapt to climate change (Akinnagbe et al. 2015). High value crops are been diversified into both the medium and long term. Lands in South Africa are converted from livestock farming to game farming, diversifying from planting cash crops to food crops and so on. He also explained that farmers in Tanzania plant their crops before the onset of rainfall and some immediately after rain starts (staggered planting) to help reduce the risks associated with rainfall variability. Smallholder farmers across the sub-Saharan Africa also diversify their livelihood as a means of adaptation strategy, Antwi-Agyei, (2012). They diversify into other activities that have varying risks associated with them so as to help boost their income. Other strategies adopted by farmers across the continent includes; improved use of irrigation systems, change in time of planting and cropping pattern, soil conservation techniques, planting of trees (afforestation) and agroforestry, to mention a few. However, a lot of these strategies still needs to be shared amongst communities in various countries.

Small holder farmers in west Africa also used some strategies to cope with climate change impacts as described by Ngigi et al. (2009) water were been used more efficiently through the use of drip irrigation system, and planting of high-yielding crops, use of shallow well and hand-dug wells to

supply water during dry season, use of drought-resistant crop varieties, practice of agroforestry, crop rotation and rainwater harvesting has also been very effective to cope with climate change in Nigeria, Senegal and some other countries in West Africa. Agricultural diversification such as the integration of livestock and crop (mixed farming) has also yielded good results to cope with climate change impacts in some other parts of the countries.

Kurukulasuriya and Mendelsohn, (2008) carried out research in crop adaptability to climate change across different 11 countries in Africa (Senegal, Niger, South Africa, Zambia, Zimbabwe, Burkina Faso, Cameroon, Egypt, Ethiopia, Kenya and Ghana) and these findings confirmed that switching of crops to match the present climate at every point in time is a very good adaptation strategy for the farmers who plant primary crops across Africa.

South Africa is experiencing increasing number of hotter days and decreasing frequency of cold days which has led to increased variability in rainfall and drought occurrence. However, to combat or cope with these climate change impacts, some adaptation actions are been put in place or followed at the national level, community level or farm level. The department of environmental affairs (2013) identified some adaptation measures that have been taken by farmers in South Africa under the climate adaptation strategy (2011) of SADC Countries at farm level. These Includes: sensitization of the public on climate change, development of indigenous knowledge and technology, improved irrigation and drainage system, change of planting time, conservation tillage practices to reduce soil erosion and reduction in loss of soil moisture content. Elum et al. (2017) described that planting of drought-resistant varieties was the most common adaptation action taken by farmers during hot seasons to cope with climate change impact. Ngigi et al. (2009) also described some adaptation strategies that were put in place at the national level to help cope climate change impacts. They include; technological innovations, use of government subsidies, farm production practices such as use of irrigation systems and timing of farm operations, farm financial management such as use of crop insurance and income stabilization programs, to mention a few.

Limpopo Province of South Africa is getting warmer as a result of increased temperature and low rainfall, farmers in this region are well aware of this fact (Maponya et al. 2014) hence, it has led to increased frequency of droughts, changes in the timing or rainfall, and so on hence the need for them to adopt some adaptation strategies to be able to cope with the changes in climate. Crop management strategies that were adopted by the farmers include, crop diversification, planting of different crops, use of different planting dates and so on. Also, some soil fertility management strategies were recognized and used by the farmers to help them fight against climate variability and its changes; use of fertilizers, pesticides and chemicals are seen to have helped farmers improve their crop yield in Limpopo Province. They make use of Organic fertilizers which are made from composting, they believe that this will help them to store carbon in the soil hereby contributing to the reduction of GHG emissions. This strategy is also supported and recognized by IPCC, (Intergovernmental Panel on Climate Change and European Union) as carbon sequestration in soil helps to mitigate greenhouse gas emission. A lot of researchers have pointed out and recognized different adaptation strategies that have been adopted by farmers across the globe, however these strategies or actions need to be put in place at various levels of the government; the national, international and farm level across the globe in different countries to be able to create more awareness about climate variability and changes and be able to create strong adaptive capacities for them.

2.17 Chapter summary

An overview of climate change was given in this chapter, its definition and how it has affected the world as a whole. It further explains how climate change has affected agricultural productivity across the world. A detailed information was also given on how its effects has impacted global environmental change, the problems it has led to and how farmers across Africa and the world at large perceived climate change. Furthermore, farmers' knowledge of climate change was discussed and their decision-making process on how they can cope with these impacts.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methods that was adopted for the purpose of this research study. Areas where the research was carried out is explained in this chapter and describes its location on the map which is covered in square kilometers. It explains the population of the area which comprises of diverse race and ethnic group and describes the local municipalities in the districts which serve as the study area for the purpose of this research. Research design and methodology used for the study is also explained in this chapter, this includes: the population, sampling, data collection, analysis and instruments used, ethical considerations, data reliability and validity. This chapter covers the conceptual and empirical framework of this study

3.2 Study Area

For the purpose of this study, the research was conducted in the Limpopo Province of South Africa. Limpopo is located in the northern part of the Country. This province was named after a river (Limpopo River) that flows through it and the name "Limpopo" originated from the Sepedi word "diphororo tsa meetse" meaning strong gushing waterfalls. The capital of Limpopo is Polokwane and was formerly called "Pietersburg". Limpopo Province was created from Transvaal Province in 1994 which is the northern part of the country and was named "Northern Transvaal" which was later changed the following year to "Northern province". The name was changed in the year 2003 to "Limpopo province" (Wikipedia, 2016).

Poverty is seen to be increasing in South Africa with Limpopo province having the highest percentage rate of 78.9%, people living in poverty in the province live below the national poverty index (https://www.polokwanecity.co.za). It is said to have five municipal districts (Capricorn, Mopani, Sekhukhune, Vhembe and Waterberg) which is subdivided into 22 local municipalities. Stats SA (2019) described population to be approximately 5.4million and they are identified by their culture, language and race, 97.3% of the population are black, 2.4% are white, 0.2% are colored, 0.1% are Indian/Asia.

Figure 3.1: *Map showing the five districts which comprises of Limpopo Province (Source: Limpopo Municipality, 2019)*

A lot of agricultural activities is being described to take place in Limpopo province hence it is seen as the breadbasket of the nation. It is recognized as South Africa's most important agricultural region because it is a major producer of livestock, fruits and vegetables (Klynveld Peat Marwick Goerdeler-KPMG report 2015). It is also regarded as the largest producer of various crops in the agricultural market because its climatic condition allows for two or more crops to be planted and grown on the same land, at the same time, in the same season (Stats SA 2011). For this reason, the choice of choosing Limpopo Province as the study area was made. The choice of the study area selected is also directed to brighten up more on the level of how farmers are aware of the changes in climate and its variabilities on agricultural crop productivity among rural farmers because these farmers depend more on livelihood activities that are sensitive to climate change impacts. They have lesser or no resources available to them compared to the urban settlement and as a result of this, they are being faced the more with the potential risks associated with the impacts of changes in climate variabilities.

Limpopo Province forms part of a three-pillar economy namely tourism, mining and agribusiness. Much of the land is made of mixed woodland ecosystem and trees and incorporates both the tropical and subtropical climate characteristics. The woodland area is beef cattle country, where controlled hunting is used to augment extensive ranching operations. Majority of the country's game hunting industry which results to about 80% is found in Limpopo Province (Stats SA, 2019). Bela-Bela and Modimolle area of the province are known to be areas where table-grapes are grown and also maize, peanuts, cotton and sunflowers (Agri-book digital 2020). Tropical fruits like banana, litchis, pineapples, mangoes and pawpaw are grown in the Tzaneen and Louis Trichardt area. Citrus, tea and coffee plantations as well as forestry are also grown in this part of the province.

Rich mineral deposits such as the platinum group materials, iron ore, chromium-high and coal, diamonds, antimony, phosphate and copper as well as mineral reserves such as gold, emeralds, scheelite, magnetite, vermiculite, silicon and mica are all found in this province and is also popular for fruits and vegetable production which includes avocadoes, tomatoes, mangoes and papaya to mention a few. It is the biggest producer of avocadoes and tomatoes in South Africa while there is 3590 hectares of land under tomato production thereby accounting for 75% of the total area under tomato production in South Africa (Department of Agriculture, Fishery and Forestry - DAFF, 2017). This is another reason why this province is chosen for the purpose of this study.

3.3 Research Design and Approach

For the purpose of this research, a quantitative approach was used, this means that the study deals with quantifying and analyzing the variables used in the questionnaire to get results. This method is used to achieve a comprehensive understanding of the research's purpose and validation (Johnson et al. 2007). The numerical data that was collected was utilized and analyzed using specific statistical techniques to answer the questions who, what, where, when and how. Kumar (2005) defined a research approach as the methods, strategies and ideas outlined by a researcher to be followed in order to achieve the aims and objectives of its research. According to Leedy et al. (2009), quantitative research involves the grouping, inspecting and elucidation of numeric data, which are collected either by survey methods, experiments or interviews using structured and unstructured questionnaires. Based on the objectives of this study, the descriptive method was used. This shows that associations were established between variables to get an overall interpretation of the results (Creswell, 2014).

3.4 Population of the Study

The sampling of the study was done by dividing the population across the local municipalities that made up the three districts that was chosen in the Limpopo Province (Vhembe, Capricorn and Mopani). Total number of farmers that practice small scale crop production resulted to 15870 farmers in the study area. Profile data of the farmers was collected from the Department of Agriculture and Rural Development, Limpopo Province. Numbers of small holder farmers who practice crop farming residing in each local municipality in the study area as well as the dominant crop in each municipality were the determinant factors used in selecting the population size.

3.5 Sample Size and Sampling Procedure

For the purpose of this research study, two crops were considered (avocado and tomato). These crops were chosen because there has not been a lot of research findings that was carried out on how climate change has affected avocado and tomato farming and its productivity particularly in Limpopo Province. A multistage sampling technique was used for this study. The criteria for participation of the farmers were based on their cultivation the crops in at least two farming

seasons. The two-stage sampling technique was used because at different stages of sampling, different sampling methods were adopted. Firstly, three districts (Vhembe, Capricorn and Mopani) were purposively selected out of five districts in Limpopo Province, this was due to the prevalence of production of the selected crops in the districts. Sample frame, containing the list of farmers who cultivated at least one of the targeted crops (avocados and tomatoes) was obtained from each selected district. In line with outcome of the equation 1, a total number of 376 farmers were targeted for this study. Therefore, the second stage involved a total of 125 farmers, which were randomly selected from each selected district. Out of the 376 targeted farmers, only 156 randomly selected farmers participated and managed to complete the questionnaires for the study. This shows that156 respondents comprised of 69 farmers from Capricorn, 37 farmers from Mopani and 50 farmers from Vhembe. Information such as socioeconomic characteristic (including income, sex, age, land ownership, farm size and farming experience) of the farmers and dichotomous variable on farmers' awareness of climate change were gathered from the respondents. The 376 farmers were selected following a sample size formula, which was expressed as.

$$ss = \frac{z - score^2 p(1-q)}{margin\ error^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots equation\ 1$$

Where: e is the desired level of precision (margin of error) which is at 5%. The symbol p is 0.5 derived as the proportion of targeted crops to be participant of the studies., farmers would be participant if he/she produced at least one of the two targeted crops. The symbol qi 1- P. z- value is found in a z-table. This formula is used at 95% confidence level which gives a 1.96 z- value.

3.6 Data Collection

Primary and secondary data information were gathered and used to achieve the aims and objectives of this study. The secondary data included temperature, rainfall and humidity data for the past twenty years for the three districts that were selected as well as data on crop yields and area under production for the past twenty years. This data was obtained from The Department of Agriculture and Rural Development, Limpopo Province.

A partially structured questionnaire was provided to collect primary data. This questionnaire contained both open and close ended questions which targets small scale crop farmers. The sections in the questionnaire were focused on the socio-demographic characteristics of the respondents (farmers), land characteristics, information on changes in climate and awareness, observations on climate change and farmers' adaptation measures. Five questionnaires were pre-tested and administered to five respondents before the actual data collection. The respondents used for pre-test did not participate in the main interview. Amendments were made and a final questionnaire was developed, see Appendix A. The pre-testing was done to test the reliability and validity of the study.

3.6.1 Data Collection Procedure

Primary and secondary data were collected for the purpose of this study. Prior to administering the questionnaire, permission to collect data was sorted from the Department of Agriculture and Rural Development, Limpopo Province and subsequently in the districts and local municipalities. Interviews were conducted face-to-face and information were gathered from the respondents using a structured questionnaire written in English. With the help of a translator, the questionnaire was translated to the local languages (Tshivenda, Sesotho, Xitsonga) before been administered to the farmers. The survey was carried out between September and December 2019. The Department of Agriculture and Rural Development, Limpopo Province, assigned managers and extension workers in the districts to help the researcher with the data collection process. Hence, the interviews were conducted by both the researcher and the extension workers. The extension workers assisted with booking meetings with the farmers in their various localities who were willing to participate in the study. The objectives of the study were explained to the respondents during the interview to enable them fill- in the questionnaires properly.

3.7 Reliability and Validity

Reliability is the steadiness yielded by a measuring instrument when used to measure a certain entity to yield results when the entity been measured hasn't changed (Leedy et al. 2010). The

validity of a measuring instrument is the degree to which the instrument accurately measured the variables of interest (Leedy et al. 2010). Both validity and reliability reflect the extent of consistency and accuracy of the data used for analysis. Since the dependent variables was dichotomous in nature, the econometric model will yield valid results using linear probability model (logit). Cronbach Alpha procedure was recognized in this study to estimate the reliability or internal consistency of the variables used for econometric analysis. The formula for Cronbach's alpha was given as:

$$\propto = \frac{N * \bar{c}}{\bar{v} + (N-1) * \bar{c}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. equation\ 2$$

In equation 2, N represented the number of items, identified as the $\bar{c}$ was the average covariance between item-pairs and $\bar{c}$ denoted as the average variance. A total of nine (9) variables were considered for regression analysis. Table 1 reported the result of the Coefficient Alpha. The result showed that coefficient (64%) of the Alpha was consistent in measurement with 27% error variance, meaning the data were reliable to provide the good results. The coefficients of each variable of interests (items) were also not bad for generating good econometric estimates (Table 1).

Table 1: Cronbach Alpha's reliability results

Item	Observation	sign	Item test correlation	Item-rest correlation	Average inter-item correlation	Coefficient Alpha
Age	156	+	0.5082	0.3179	0.1621	0.6074
Gender	156	-	0.2691	0.0521	0.2009	0.6678
Education level	156	+	0.4934	0.3014	0.1642	0.6111
Land Ownership	156	-	0.3764	0.1678	0.1832	0.6422
Farm Size	156	-	0.7345	0.6049	0.1248	0.5328
Main occupation			0.5388	0.3553	0.1563	0.5971
Source of Income	156	+	0.3830	0.1690	0.1830	0.6418
Experience	156	+	0.5990	0.4292	0.1466	0.5788
Awareness on climate change	156	+	0.6548	0.5000	0.1374	0.5603
Scale reliability coefficient					0.1620	0.6351

3.8 Data Analysis

To satisfy the aims and objectives of this study, the following analytical procedure were used; descriptive analysis and inferential methods. Data was cleaned, coded and entered on Microsoft Excel and STATA version 14 for the descriptive and inferential measures respectively. The descriptive analysis includes frequency distribution, percentages and mean and most of the data was categorical data so descriptive statistics were used to present the main findings that address the objectives of the study. The inferential method involves the use of binary logistic regression model (BLRM) to address the hypotheses of the study and to determine the factors that influence crop farmer's decision to adapt or not to climate change.

3.9 Descriptive Statistics

Descriptive analysis used include means, frequency distribution and percentages. This is used to analyze the socio-economic parameters such as age of the farmers, education level of farmers,

gender of farmers, access to extension officers and farm size. Objectives 1, 3 and 4 of the study was achieved by analyzing the descriptive statistical data gathered from the empirical evidence.

3.9.1 Binary Logistic Regression Model

The binary logistic regression model was used to determine the factors that influence farmer's decision to adapt or not to climate change. The binary dependent variable was a dummy for undertaking any adaptation at all where Y_i has only two possible values, 1 or 0 for either adapting or not to climate change. The independent variables took the form of both categorical and continuous. Therefore, this model considers the relationship between a binary dependent variable and a set of independent variables. The binary dependent variable is a dummy for undertaking any adaptation at all which takes the value 1 and 0 if otherwise. A farmer will be considered to have adapted to climate change if he or she employs at least one of the adaptation strategies that will be listed in the questionnaire.

The binary logit regression is presented as follows;

$$PY_i = 1 = \frac{expexp\,[X^i\beta^i]}{expexp\,[X^i\beta]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$P\,(Y_i = 0) = 1\text{-}P = 1\text{-}\left(\frac{\exp(X^i\beta}{1+expexp\,(X^i\beta)}\right) = \frac{1}{1+expexp\,(X^i\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where: P(Y=0) represents the probability of a farmer not adapting to climate change

P(Y=1) represents the probability of a farmer adapting to climate change

$X^!$ represents the sets of all the independent variables that determine the farmers' probability to adapt to climate change

β coefficient represents the explanatory power of the independent variable.

The binary logit equation in its explicit form will be expressed thus;

$$Adapt^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots\cdots\cdots \beta_n X_n \quad \text{———} \text{(3)}$$

$$\text{Adapt} = \beta_0 + \beta_1 sex + \beta_2 age + \beta_3 educ + \beta_4 landowner + \mu_i \quad \text{———} \text{(4)}$$

Where adapt * is unobservable and adapt is observable which is the different adaptation measures employed by the farmer.

μ_i is the error term, this is a standard logistic distribution.

β_0 is constant term

β_1 is vector of coefficients

X_1 is vector of the explanatory variable

The logit model could be written in terms of odds and log of odds ratio to enable comprehension of the interpretation of the coefficient. This odd ratio is a linear function of the independent variables. From equation 1and 2, the odd ratio for a logit model can be written as

adapt= $\left(\frac{1\ if\ adapt^{*} > 0}{0\ if\ adapt^{*} \leq 0}\right)$

The model (4) used for this study is specific below. Table 3.1 below provides a description of the variables.

Adapt = $\beta_0 + \beta_1 sex + \beta_2 age + \beta_3 educ + \beta_4 landowner + \beta_5 mainoccu + \beta_6 farmsize + \beta_7 income + \beta_8 experience$

Table 3.1: Definition of Variables

Variable	Definition	Measurement
Sex	Farmer's gender	Male= 0 Female= 1
Age	Age of the farmer	< 35 years=0 36-45 years=1 46-55 years = 2 >55 years=3
Educ.	Highest education level of the farmer	Tertiary = 0 Secondary level=1 Primary level=2 No education=3
Land ownership	Land tenure system of the land the farmer is using	Privately own =0 Communal =1 Other = 2
Main occupation	The respondent's main occupation	Farming = 0 Employed =1 Self-employed=2 Other =3
Farm size	The size of the farm	< 2 hectares(ha) = 0 1-5ha=1 6-10 ha= 2 >10ha
Income	If farming is the main source of income	Yes = 0, No =1
Experience	Years of farming experience	< than 2 years = 0 2-5 years =1 6-10 years = 2 > 10 years

Marital status	The farmer's marital status	Single = 0, Married =1, Other = 2
Awareness	If the farmer received information on climate change awareness	Yes = 0, No =1
HH size	Number of members in the household	< 4 members =0 4-5 members =1 6-7 members =2 > 7 members = 3

3.10 Ethical Clearance

Resnik (2015) defined Research ethics as the rules for distinguishing between right and wrong (norms for conduct). De Vos *et al.* (2015) also defined research ethics as the set of attitudes from a researcher that guarantees some regard for the privacy, rights, integrity and confidentiality of those that will participate in the research. Some processes were followed by the researcher to make sure this study is ethically accepted and approved. It followed strictly the University's policies on ethical clearance, the research proposal was approved by the ethics committee of the institution and approved by the rights of the participants, which did not cause harm to the participants in anyway.

For the purpose of this research, a written consent letter was obtained from the department of Agriculture and rural development, Limpopo Province to carry out the research. This letter was also sent to the people that are needful for the research for example, those in charge of information regarding climate change within the province so as to access their database for the purpose of the research. This research study used human participants; hence these respondents were treated with

confidentiality and were also informed about the benefits of the research to their livelihood and society as a whole.

3.11 Chapter Summary

This chapter presented detailed information about the study area. It discussed the sampling methods that was used for the purpose of this study, the way in which data were collected and analyzed. The instruments used in collecting the data was explained in detail and the validity and reliability of the study was explained. Five questionnaires were tested to check its validity and reliability before the final analysis was done and 156 Small holder farmers were interviewed to fulfil the aims and objectives of this study.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion of the key findings of this study. The results for the demographic characteristics of the respondents were presented using the descriptive statistics and inferential analyses using the binary logit model are presented.

4.2 Demographic Characteristics of Respondents in the Study Area

4.2.1 Frequency distribution of respondents across the districts and local municipalities in the province

Respondents were distributed according to the districts they belonged to in the study area, this is shown in Table 4.1. The research was carried out in the Limpopo Province of South Africa and the following districts were visited: Mopani, Vhembe and Capricorn. The following local municipalities were selected from each district for the study; Mopani District (Greater Giyani, Tzaneen and Ba-Phalaborwa), Capricorn District (Blouberg, Molemole, Polokwane, Lepelle-Nkumpi and Mashashane), Vhembe district (Makhado and Thulamela). The information gathered from the secondary data helped in distributing the population among the local municipalities based on the frequency of crop farmers available in each municipality. A purposive sampling was used to select the local municipalities that mainly cultivates each crop that was selected for the purpose of this study as informed by the extension officer. The results showed that 69 respondents were from the Capricorn District thus attracting 44.2% of the total respondents, Vhembe had 50 respondents thereby having 32.1% of the total respondents while Mopani District had the least number of respondents of 37 which amounted to 23.7%of the total respondents.

Table 4.1: Frequency distribution of farmers across the districts

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
District	Capricorn	69	44.2
	Vhembe	50	32.1
	Mopani	37	23.7
	TOTAL	**156**	**100**

Source: Data used from the survey (2019)

4.2.2 Socio-economic characteristics of the respondents according to their age group

According to the results shown in Table 4.2, respondents under the age of 35 years accounted for 21.3% of the respondents, age range between 36-45years constituted 21.9%, 46-55 years accounted for 29% of the respondents while the remaining 27.7% amounted to the respondents' age group above 55 years. This means that most of the participants are between the age of 46-55 years who are the middle-aged people. It also shows that older people who are above the age of 55 years are actively involved in farming practices in the study area. Therefore, looking at the farming activities in the study area, percentage age between 46-65 actively engage in farming activities, this can imply that other age groups do take part in farming activities but not as much as the middle-aged group taking part in agricultural production in the study area. This is because most young people in Africa pursue other employment opportunities that are more attractive than farming (Oduniyi 2014). Several studies have shown that there is variation in age on adoption decisions. According to Maponya and Mpandeli (2012), age is a determinant factor in adopting climate change adaptation measures, more experienced and older farmers are expected to adapt more to changes in climate than the young ones. Ibrahim et al. (2015) also explained in his findings that farmers who are older are believed to be more experienced hence they are able to adopt adaptation measures to help them cope with climate change impacts to positively impact their productivity.

Table 4.2: Frequency distribution of respondents according to their demographics

CHARACTERISTICS	**CATEGORY**	**FREQUENCY**	**PERCENTAGE**
Age group	Under 36 years	33	21.3
	36-45 years	34	21.9
	46-55 years	46	29.1
	Over 55 years	43	27.7
	TOTAL	**156**	**100**
Gender	Male	106	68.0
	Female	50	32.0
	TOTAL	**156**	**100**

Marital Status	Single	38	24.4
	Married	93	59.6
	Divorced	12	7.7
	Widow	13	8.3
	TOTAL	**156**	**100**
Educational Level	Primary	42	26.9
	Secondary	60	38.5
	Tertiary	48	30.0
	No education	6	3.8
	TOTAL	**156**	**100**
Household Size	< 4 members	27	17.3
	4-5 members	74	47.4
	6-7 members	34	21.8
	>7 members	21	13.5
	TOTAL	**156**	**100**
Major Occupation	Farming	115	73.7
	Employed	22	14.1
	Self employed	12	7.7
	Business	1	0.6
	Pensioner	6	3.9
	TOTAL	**156**	**100**
Farming as major source of Income	Yes	118	75.6
	No	38	24.4
	TOTAL	**156**	**100**

Source: Data used from survey (2019)

4.2.3. Socio-economic characteristics of respondents according to gender

From Table 4.2, 68.0% of the respondents are male while 32.1% accounted for the female respondents. The reasons for having higher number of males than females may be as a result of the fact that agricultural activities are very strenuous and require physical labor and the female counterparts may not be as strong as the male farmers to carry out these activities. Despite this, different studies have proven that gender of the farmer is an important determinant factor in adopting adaptation strategies especially at the farm level.

Nhemachena and Hassan (2007) reported that female farmers have more farming experience and are well informed about climate change than male farmers because they take part more in agricultural activities especially the rural based small-holder communities. Men often move to towns to help support their families' livelihood making women to take part more in agricultural activities, hence they tend to engage more in adopting adaptation measures and taking up good management practices. In contrast to this, Berhe et al. (2017) explained that females in the rural Ethiopia do not actively take part in agricultural activities because of their cultural hindrances which obstruct them from engaging in various development activities outside their homes. They highly engage in family management such as cooking, washing and taking care of the children thereby leaving the males to be actively involved in agricultural activities. Also, Oduniyi (2018) connotes that farming are predominantly for male while females sell the agricultural produce and process it. He further elaborates on how different gender engaging in farming activities can depend on cultural standards as some farming activities such as ploughing and spraying rely solely on access to male labor. The results shown in table 4.1 has therefore proved the notion that males take part more in agricultural activities than females.

4.2.4. Characteristics of the respondents according to their marital status

Table 4.2 shows that 24.4% of the participants are single, 59.6% are married, 7.7% are divorced while 8.3% of the participants are widowed. These findings showed that most of the respondents are married. This means marital status of farmers may have influence on the amount of knowledge

farm households have on climate change awareness and adaptation through the head of the family or any other member of the household. This is also explained by Titus et al. (2015), who reported that agricultural production is mainly practiced by married people.

4.2.5. Distribution of respondents according to their level of education

A small proportion, 3.8% of the respondents do not have any form of education. About 38% of the farmers indicated that they attended secondary school which is their highest level of education attained whilst 30.8% of the respondents have attended tertiary school and 26.9% have primary school education. The tertiary level consists of those that attended universities, colleges and vocational training whilst the secondary school level comprised those who have been to high school and adult education. According to Oduniyi (2018) the level of education of a farmer can help improve on the farmers' livelihood and its household and their level of awareness on climate change and its impacts, knowledge towards adoption and better farming practices.

4.2.6. Household size of the respondent

Respondents are distributed according to the size of their household and this is represented in Table 4.2. The result of the survey showed that the household with the largest size are between 4-5 in number with a percentage of 47.4%. This is followed by those whose household size ranges between the number 6-7 members with a percentage of 21.8%. The household that has less than 4members holds a 17.3% while the least goes to households that has more than 7members accounting for 13.5% of the total respondents. From these results, it can be depicted that the average size of a household in the study area is of a medium size which ranges between 4-7 members. However, these findings have indicated that it is possible that the households with large numbers can be used as a source of labor force on the farm if they all participate in farming activities thereby leading to improvement in agricultural production. On the contrary, Sadiq *et al*., (2019) alluded that households with larger size tends to use part of its labor force on non-farming activities so as to help alleviate poverty within the family. This research finding however is been supported by Mugula and Mkuna (2016) who reported that farmers with larger household size are

more likely to make use of proper management practices for their agricultural production which in turn helps them to have higher production and are more likely to adapt to climate change.

4.2.7. Distribution of respondents according to their major occupation

Table 4.2 reveals that farming which accounted for 73.7% of the respondents is the major occupation in the study area. 14.1% of the participants are formally employed, 7.7% are self-employed, 0.6% of the participants engage in one form of business or the other while 3.9% of the respondents are pensioners. According to this finding, majority of the respondents engage mostly in farming as their major occupation and the reason might be due to the fact that most of them are small holder farmers who are not interested in any other form of occupation or they do not have any other form of occupation except farming. This finding is however supported by Fleshman's (2007) research, which explained that agricultural production in Africa which is mostly supported by rain, provides job opportunities to over 70% of the labor force. Mendelsohn (2008) also explained in his research that most developing countries are more dependent on farming as their major occupation most especially those in the rural area.

4.2.8. Distribution of the respondents according to their source of income

The findings of this study revealed that farming was the major source of income and livelihood for most of the respondents (68.0%) while the remaining 32.0% rely on other sources of income, this result is indicated in Table 4.8. This connotes those farmers in the study area takes agricultural production activities very seriously and it is the major source of income and livelihood for the households. This corroborates the findings of the Montpellier Panel report (2015) that agriculture serves as a revenue earner and the biggest employer in most African countries. It also supports IFAD's (2011) report that most rural dwellers of about 80% engages in farming activities while only 10-20% of households from the rural areas in sub-Saharan Africa derive their source of livelihood or income from engaging in non-farming activities.

4.2.9. Distribution of respondents on the reason of crop cultivation

According to DAFF (2018), the Limpopo Province produces the majority of avocados and tomatoes in South Africa. Approximately 60% of the avocados are produced in South Africa and 3590 hectares of land is under tomato production. For this reason, the study focused on the two crops: avocados and tomatoes. The farmers were asked if they produce avocado or tomatoes or both and were further asked their main reason for producing the crops. Majority of the respondents 45.5% as shown in Table 4.3 sold their produce remains after personal consumption. 33.0% of the respondents' sole aim was for personal consumption while 21.5% of the respondents were producing for commercial or industrial purpose. This finding is supported by Yaro (2006) report that small holder farmers take their excess production to the market to sell in which they use to support their source of livelihood and meet their financial needs.

Table 4.3: Frequency distribution on the reason of crop cultivation

Reason for cultivating	Frequency	Percentage (%)
Personal consumption	93	45.5
Surplus sold	40	33.0
Commercial/ industrial purpose	23	21.5
TOTAL	**156**	**100**

Source: Survey data (2019)

4.2.10. Distribution of respondents according to land tenure system

Figure 4.1 shows the distribution of the respondents according to the type of land tenure system that were adopted by the farmers in the study area. From the findings, it is evident that the system was controlled mostly by communal land system with 79.5%. 10.3 percent of the farmland was occupied by the respondents through permission to own or occupy, 8.9% of the land were personally owned by the farmers while the remaining 1.3% were occupied through other means either by renting/ leasing or through land reform programs. This study shows that most farmers occupy their farmland through communal land tenure system which means that the lands are either owned collectively by an extended family, clan, community or even

ancestral related people but allows them to cultivate the land in exchange for a levy. This implies that the farms are well managed and proper adoption process are executed in contrast to other types of farm land so as to generate enough produce to sell in order to meet the family's needs to maintain a livelihood and be able to pay the levy on the farm at the appropriate time. Statistics South Africa (2016) also revealed that 4.5% of the agricultural activities in the Limpopo province of South Africa are done on communal land.

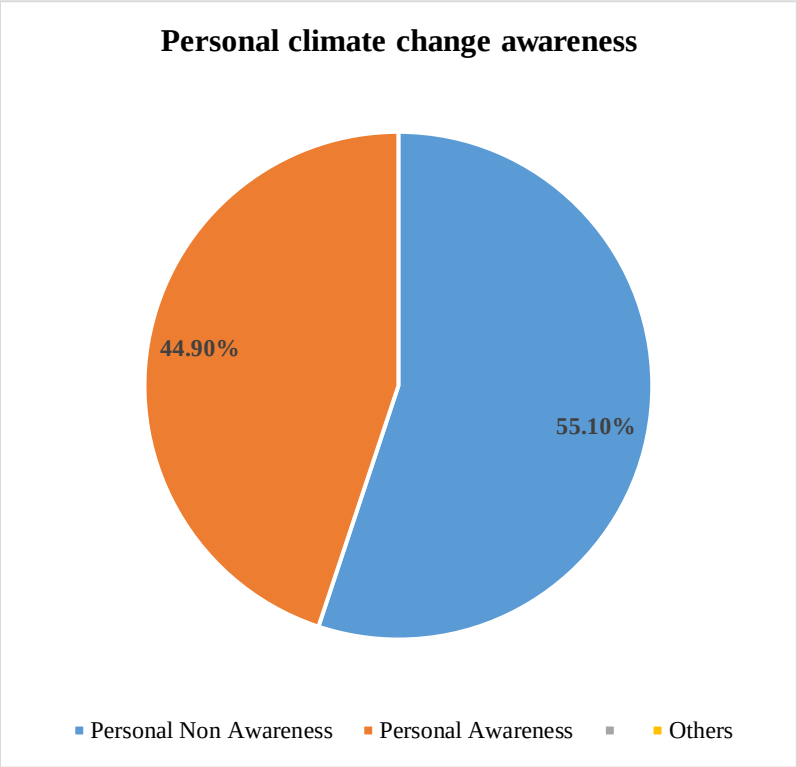

Figure 4.1: distribution of the respondent according to the land tenure system (Source: Survey, 2019)

4.2.11 Respondents' distribution according to who manages the farm

Table 4.4 shows that most farms were individually managed at 52.6%, 26.3% of the farms were managed by families, 8.3% are managed by farmer's group, 7.7% managed by companies while 5.1% are farms that are managed by trust. This implies that Individual will manage their farms well by ensuring that they make use of the required and important resources required for the farming season, this in turn makes adoption of adaptation strategies, adoption of new technological

changes and changes in the style of livelihood easier. Maponya (2021) however supported these findings by reporting in his research that most farms in Limpopo province of South Africa are owned and managed by independent farmers.

Table 4.4: Frequency distribution of respondents according to farm manager

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
Farm management	Individual	82	52.6
	Family	41	26.3
	Farmers' group	13	8.3
	Company owned	12	7.7
	Trust owned	8	5.1
	TOTAL	**156**	**100**

Source: Survey Data (2019)

4.2.12. Respondents' distribution according to farm owner

Table 4.5 shows the distribution of the respondents according to how they own the farm. This survey shows that most farms are owned by family members with 54.5%, individual owner 14.1%, farmer's group owns 18.6%, 9.6% is owned by companies while 3.2% is trust owned. This implies that the respondents (farmers) prefer to own their farms as family and not as a group or individual. The family nominates a certain member or members of the family to possess the land in order to take full management of the farm. This enables them to pay more attention to climate changes and how they can cope with it so as to improve their yield.

Table 4.5: Frequency distribution according to the owner of the farm

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
Farm ownership	Individual	22	14.1
	Family	85	54.5
	Farmer's group	29	18.6
	Company-owned	15	9.6
	Trust-owned	5	3.2
	TOTAL	**156**	**100**

Source: Data used from survey (2019)

4.2.13. Distribution of respondents according to the size of the farm

From this survey, a great number of the farmers cultivates on the farm size lesser than one hectare with a 33.3% while those cultivating on the farm size between 1-5 hectares is 30.1%. Nine percent cultivated on farm size between 6-10 hectares, 8.3% between 11-15 hectares, 7.1% between 16-20 hectares while 12.2% were owned by farmers who cultivated on the farm size that is above 20 hectares. This statistic is illustrated in Figure 4.2. This means that the average farm size cultivated by farmers in the study area is between 0-5 hectares. This has showed that agricultural production especially crop farming in the study area is mainly done by smallholder farmers which is supported by DAFF (2012) report, Ren et al. (2019) that small holder farmers are deemed to be the drivers of the economies and play a critical role in enhancing agricultural sustainability. This is also largely supported by Chenchen et al. (2019) research which also says that China's agricultural sector is still largely dominated by small holder farmers which plays a critical role in agricultural sustainability.

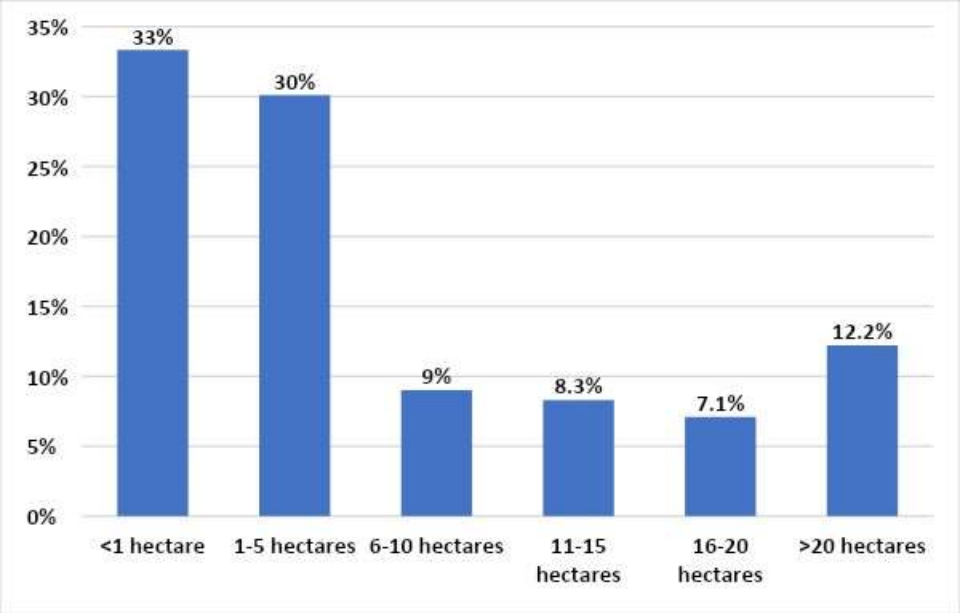

Figure 4.2: farm size of the respondent (Source: Survey data, 2019)

4.2.14. Distribution according to the type of crops cultivated by the respondents

For the purpose of this research, two types of crops were looked into which is avocado and tomatoes because these crops are mostly cultivated in the Limpopo Province of South Africa (DAFF 2018) which is the study area. Also, these crops were looked into because there had been very few research studies that has been done to understand the impacts of changes in climate on these crops and how farmers can adopt adaptation strategies to cope with its effects and the factors that influence the adaptation measures adopted by the farmers especially in the study area. Table 4.6 hence showed the percentage distribution of the crops cultivated by the respondents in the study area. 6.4 percent of farmers cultivated avocado only, 23.7% cultivated tomatoes only while majority of the respondents cultivated both crops resulting to 69.9% of the farmers. This research findings showed that because most of the respondents in the study area are small scale farmers, they tend to engage in planting different types of crops so as to help cope with their livelihood to alleviate poverty. This finding is supported by Pienaar et al. (2015) that, small scale agriculture in South Africa plays a very important role in helping to achieve poverty reduction goals and rural development.

Table 4.6: Frequency distribution of the type of crop cultivated

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
Crop planted	Avocadoes	10	6.4
	Tomatoes	37	23.7
	Both	109	69.9
	TOTAL	**156**	**100**

Source: Data used from survey (2019)

4.2.15. Frequency distribution of respondents according to number of years in farming

As represented in Table 4.7, a total of 7.8% of the respondents had been farming for less than two years in the study area, 11.6% had been farming between 2-5 years, 14.0% between 6-10 years, 55.1% between 11-15 years while 11.6% accounted for those who had been farming for over 15 years. This shows that most of the respondents has enough years of experience in crop farming who had been farming for about 11-15 years. Also, there is urban migration which has showed enough evidence that the house-hold members migrate from the rural areas to urban settlements in search of better source of livelihood thus leading to a decreased number of years of farming in the study area. The respondents have substantial years of experience in crop farming, this will in turn give them enough knowledge about climate change and be able to participate in various adaptation strategies that will be of help to them on the farm. This was reiterated by Maddison (2007) that farmers who are more experienced have enough knowledge and information about the changes in climate and its variabilities and can employ proper adaptation measures in response to these challenges.

Table 4.7: Percentage distribution or farmers according to their years of farming

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
Farming experience	<2 years	10	7.8
	2-5 years	15	9.1
	6-10 years	18	12.0

	11-15 years	71	55.1
	>15 years	42	16.0
	TOTAL	156	100

Source: Data used from survey (2019)

4.3. Respondents' Distribution According to Climate Change Information and Awareness

4.3.1 Frequency distribution of respondents according to information on changes in climate

Figure 4.3 explained that 56.4% of the farmers had access to climate change information via different medium available while 43.6% showed that they did not receive any information on climate change. This implies that over average of the respondents had reliable access to getting information on changes in climate through different media available to them which includes media, extension services, formal schooling, their peers and personal observation. This simply means that formal extension service and other media means had a positive and significant impact on their awareness to climate change and how they can adapt or cope with its impacts. According to Adesina et al. (1995), access to extension service is very important and it positively impact the acquisition of new technologies by opening the farmers to new information and technical know-how. Farmers adapt more to changes in climate and improve on their productivity when they gain better access to extension services and information about the impacts of changes in climate (Luseno et al. 2003).

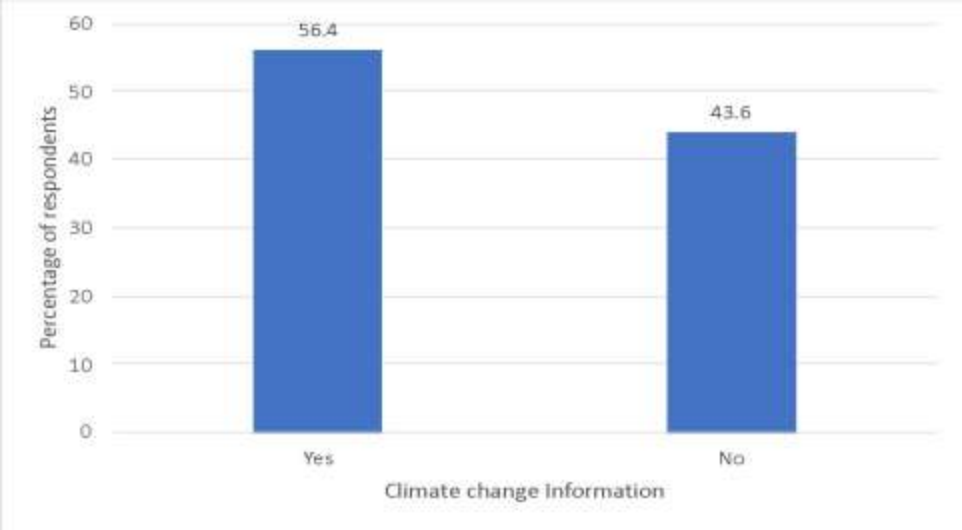

Figure 4.3: Percentage distribution of climate change information (Source: Data from Survey, 2019)

4.3.2. Respondent distribution based on climate change awareness in their locality

An average number of respondents in the study area are aware that the climate is changing resulting to 53.9% of the total respondents while 46.1% of the farmers explained that programs based on climate change awareness has not been put in place in their locality. This shows that more than average of the respondents had perceived climate change which has made them to be aware of climate change. This is related to the fact that most farmers have received information on climate change hence making them aware of its impacts on their productivity. According to Dechassa et al. (2019), explained that it is important for farmers to be aware of the changing climate and its impacts on their productivity as this will help them develop coping and proper adaptation strategies. However, it is important to still intensify free and casual training of farmers on climate change so as to be more aware in their locality about its impacts on their productivity and how to develop and adopt better coping mechanisms to deal with changes in climate.

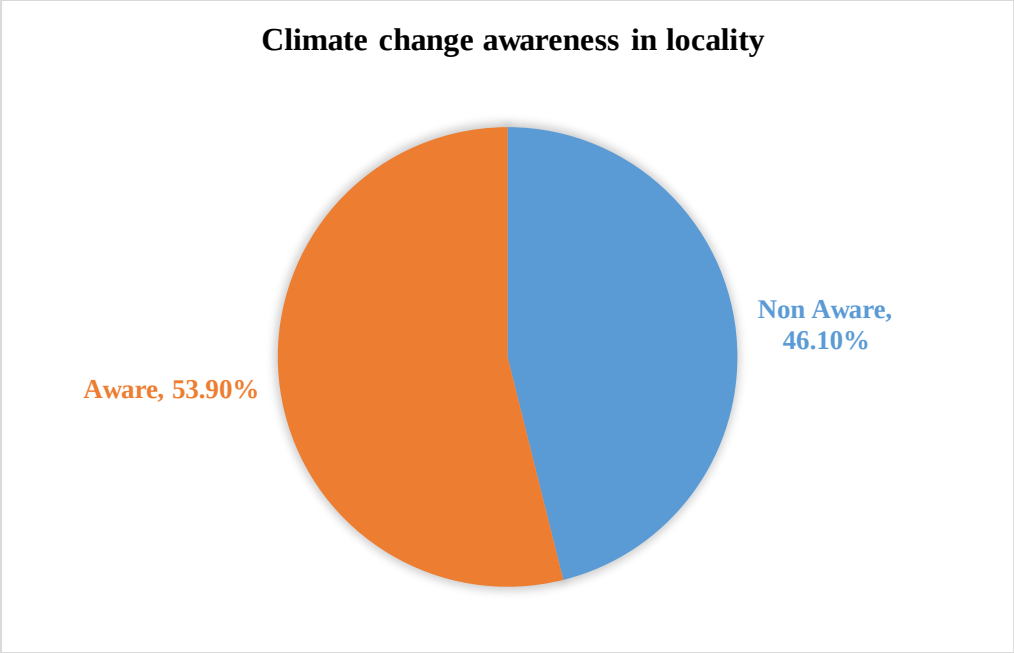

Figure 4.4: Climate change awareness in locality (Source: Survey data 2019)

4.3.3. Distribution of respondents on personal climate change awareness

Farmers in the study area were categorized according to their individual insight on climate change, they were been asked if they are personally aware about the changes in climate. This is represented in Figure 4.5. The result implies that over half of the respondents with 55.1% have a personal awareness on the phenomenon climate change in their locality. This implies that over half of the respondents understand that the climate is changing and it will have impacts on their production as it is seen that there is a relationship between level of education of the farmer and climate change awareness in Limpopo Province of South Africa. However, more awareness needs to be done in the locality so that farmers will have more knowledge on climate change and its impacts and be able to develop better adaptation strategies and coping mechanisms so as to be able to respond to natural hazards and climate variabilities.

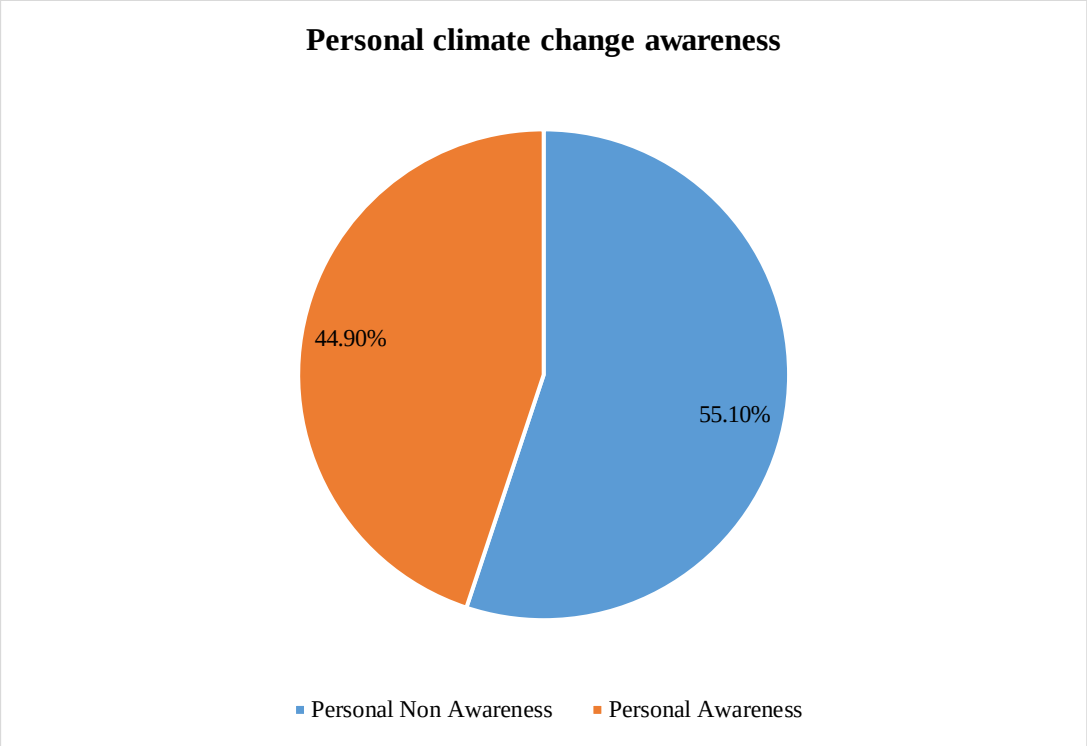

Figure 4.5: Frequency distribution based on personal climate change awareness (Source: Data from survey, 2019)

4.3.4. Distribution of respondents based on their responses to the causes of climate change in their locality

From Table 4.8, most of the respondents strongly agree with the climate change statements. Noteworthy is the 7.3% of the farmers who disagree with the statement that increased occurrence of floods in the area is as a result of the impacts of changes in climate. Wisner *et al.* (2004) argue that actions need to be taken before, during and after adverse events such as floods and droughts for them to be recognized as productive coping mechanisms. Precautionary, mitigating and after-events coping measures can be recognized as these coping strategies. Therefore, this might suggest that the perceptions of the 7.3% towards climate change and floods might be detrimental to their decision to take up any preventive coping strategies.

Table 4.8: Respondents opinions on climate change statements

Statement	Strongly agree	Agree	Undecided	Disagree
Activities done by human beings contribute to the impacts of climate change	82.6%	17.4%	0.0%	0.0%
Increased frequency of droughts is as a result of the effects of changes in climate	83.7%	14.0%	2.3%	0.0%
Increased occurrence of floods is as a result of the effects of changes in climate	36.1%	43.4%	12.1%	8.4%
Cutting down of trees and uncontrolled burning of forests contributes to the effects of climate change	75.9%	24.1%	0.0%	0.0%
Fume exhaust from cars (CO_2) also contribute to climate change	55.5%	42.0%	2.5%	0.0%
Gas discharge (emissions) from Industries contribute to climate change	47.5%	48.8%	3.7%	0.0%
Mitigation strategies on climate change can be implemented in several ways by human beings	61.0%	26.8%	12.2%	0.0%
Planting of trees (Afforestation) will help to mitigate climate change	58.2%	36.7%	5.1%	0.0%
Some areas receive more rainfall than others while some receive less rainfall than they used to receive	71.9%	28.1%	0.0%	0.0%

Source: Survey Data (2019)

4.3.5. Distribution of participants by source of climate change information

Figure 4.6 revealed the responses given by the respondents that were familiar with changes in climate. They identified how they got to know about the climate change despite claiming that

climate change awareness is very poor. The results therefore identified how important information on climate change has contributed to their knowledge about it. It was disclosed that 26.3% of the farmers knew about climate change through formal schooling, 81.2% explained it was through their own personal observation they got to know that the climate is changing. 88.9% which shows majority of the respondents acknowledged that it was through media they knew about this phenomenon. They indicated broadcasting media such as radio and television and print media such as newspapers as a major tool in getting and distributing ideas on climate change. This has however been a major contributor to their understanding on climate change. 70.2% knew about climate change through extension services either by those provided by the government or by private companies. This has also aid in their knowledge about climate change. 68.3% explained they get information on climate change through other people either from other farmers, farmers' groups or their families. From the interpretation of this finding, it is obvious that most of the respondents have more than one source at which they get information about climate change. Some farmers showed that they get their information through extension services and also through broadcasting media while some can receive their information through personal observation and still receive more information from other people.

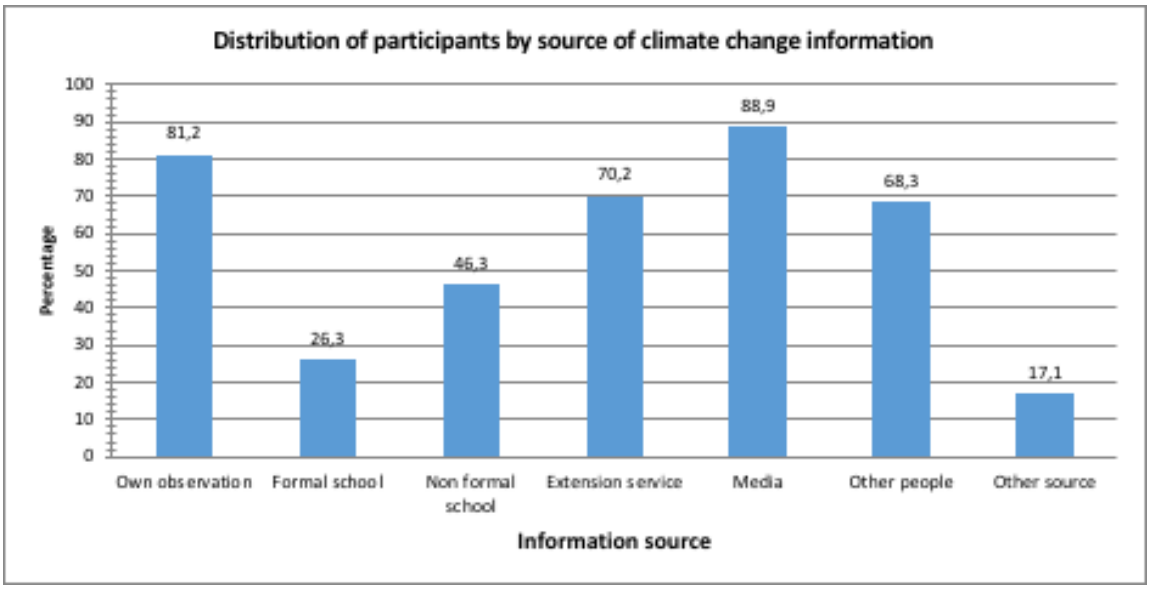

Figure 4.6: Distribution of participants by source of climate change information (Source: Data used from Survey, 2019)

4.3.6. Distribution of respondents according to the usefulness of the information received about climate change on their productivity

Figure 4.7 shows that majority of the participants, 76.9% agreed that the information they received on climate change is of immense positive help to their productivity while 23.1% says there was no significant impact of information received on climate change and its impacts on their production. This implies that more farmers are well aware about climate change, the better they cope with it. Luseno et al. (2003) explained that farmers are able to cope with climate change impact as they gain more access to extension services and information on climate change. This is also supported by IPCC (2014) report that information on climate change impact is a determinant factor of how human beings respond to and adapt to these changes to reduce their vulnerabilities to changing climate variabilities in future.

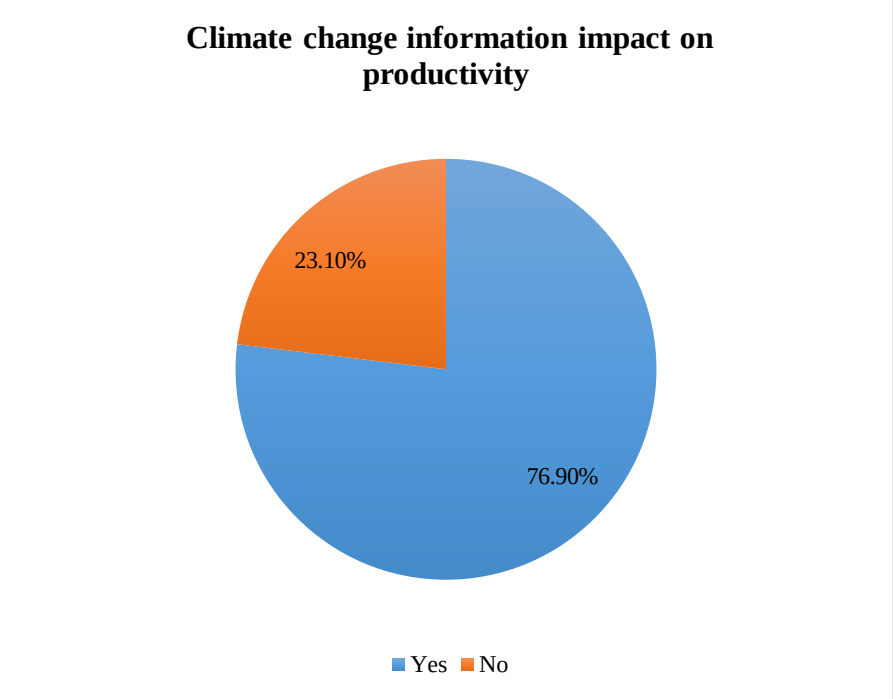

Figure 4.7: Frequency distribution of climate change information impact on productivity (Source: Data used from survey 2019)

4.3.7. Respondents' distribution according to their observation on any climatic changes

Figure 4.8 showed that most of the respondents in the study area accounting for 87.2% are familiar with the climate change phenomenon and its variables while 12.8% did not observe any changes in the climate variables. Some of these climatic variables were identified to be rainfall, temperature, wind, humidity, frost and dew. All these has however impacted their production in different ways. Rainfall and temperature were the two main climatic variables that was identified to be changing seriously in the recent years. Maponya and Mpandeli (2012) however explained in their research that changes in climate and its variabilities in the study area has affected farmers' agricultural crop production in a very bad way as impact of lower rainfall resulted in decrease in productivity, deaths of livestock, low yield and scarcity of water. The Department of Environment (2010) also reported that from 1960, the climate in the Limpopo Province has been characterized by an increase in extremely hot days and significant reduction in rainy days.

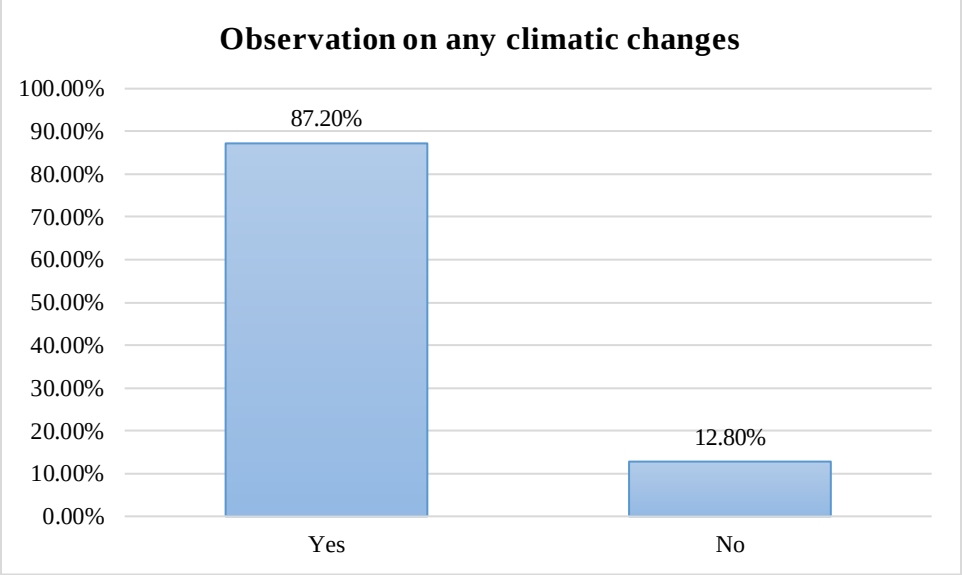

Figure 4.8: Frequency distribution according to climatic changes observation (Source: Data from Survey, 2019)

4.3.8. Respondents' distribution according to specific changing climatic variables

Table 4.9 shows the responses of the farmers on different climatic variables that were changing in the study area. About 70.5% of the respondents identified that the temperature in the study area had been on a significant increase over the recent years while few believed that it is decreasing.71.2 percent of the respondents believed that rainfall intensity is changing while 50.6% explained that drought has been on immense increase over the recent times in the study area. 26.9 percent indicated that they had experienced strong wind in recent times and 7.1% of the participant explained that they have not experienced any changes in wind in their locality.

These findings imply that temperature has been increasing since the last few years combined with low intensity of rainfall which has led to increase in the rate of evaporation, this had however led to increase in drought incidents in the study area. This was explained in Mpandeli and Maponya (2012) research that Limpopo Province is getting drier and rainfall is significantly decreasing which has altered the climate thereby leading to increased drought occurrence. This however has had a negative effect on agricultural crop production in the study area. IFPRI (2008) report by Nhemachena et al. (2014) also supported this finding by explaining a cross-sectional data that was obtained and used in research in South Africa, Zambia and Zimbabwe that most farmers identified increased temperature in the last 20 years which has led to drier conditions and pronounced frequency of droughts.

Table 4.9: Frequency distribution showing changing climatic variables

CHARACTERISTICS	**CATEGORY**	**FREQUENCY**		**PERCENTAGE**	
Changing climatic variables		YES (n=156)	NO	YES (%	NO
	Temperature	110	46	70.5	29.5
	Rainfall	111	45	71.2	28.8
	Droughts	79	77	50.6	49.4
	Strong winds	42	114	26.9	73.1

	No wind	11	145	7.1	92.9
	No changes in wind	0	0	0	0

Source: Data from Survey, 2019)

4.3.9. Distribution based on perception on long-term rainfall changes

Table 4.10 explained that most of the respondents 65.6% identified that there would be rainfall decrease in the study area in the nearest future while 34.4% explained that there would be rainfall increase in the long run. This explains that most of the respondents perceive that there will be a decrease in rainfall in the coming years in the study area. Many literatures have disclosed that grain yield in many developing countries would fall due to climate warming in the future (Sultan et al. 2019, Shew et al. 2020, Wang et al. 2018). Therefore, decreased rainfall in the study area could lead to low crop yield, low production or even poor quality of agricultural products. This result connotes with other study conducted by Tsegaye et al. (2013) which explained that crop failure is the direct cause for shortage of animal feed which is linked with low rainfall and drying of sources of water.

Table 4.10: Frequency distribution of respondents based on changes in rainfall perception

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
long term rainfall perception	Increase in rainfall	57	34.4
	Decrease in rainfall	99	65.6
	No change	0	0
	TOTAL	**156**	**100**

Source: Data used from survey, 2019

4.3.10. Distribution of respondents according to perception on long term temperature changes

Table 4.11 reveals that 96.8% of respondents in the study area identified that there would be a temperature increase in the long run in the study area while 3.2% explained their view that there will be a decrease in temperature in their locality in the coming years. This result means that if there is a continuous increase in temperature in Limpopo province over time, then there will be increased frequency of drought occurrence as most water sources (rivers, wells, ponds, streams and so on) will continue to dry-up.

Table 4.11: Frequency distribution of respondents according to perception on temperature changes

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
long term temperature perception	Increase in tempt.	151	96.8
	Decrease in tempt	5	3.2
	No change	0	0
	TOTAL	156	100

Source: Data used from survey (2019)

4.3.11 Distribution based on perception on long term wind changes

Table 4.12 shows that most of the respondents 87.6% in the study area pinpointed that there would be an increase in wind in the long term while 12.4% indicated that there would be no change at all in the velocity of wind in the study area in the coming years. Wind velocity and direction have a strong significant influence on crop growth. When there is an increase in the velocity of wind, this could lead to acceleration in drying of plants by replacing humid air with dry air thereby leading to loss in crop yield. Strong wind also damages the shoots of plants, shedding of fruits and flowers of plants, causes soil erosion and so on. This leads to reduced agricultural crop production. This

result is therefore in agreement with the studies conducted by Cleugh et al. (1998) which reported that wind directly affects crop growth rates and yields.

Table 4.12: Frequency distribution according to farmers' perception on wind changes

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
long term wind perception	Increase in wind	126	87.6
	Decrease in wind	0	0.0
	No change	30	12.4
	TOTAL	**156**	**100**

Source: Data used from survey (2019)

4.3.12. Frequency distribution of respondents according to experience with changing climatic variables

Figure 4.9 shows how the farmers responded to questions on their experience with changing climatic variables in the study area. About 59% of the farmers indicated that there has been flood occurrence in their area. 91.7% indicated that there has been an increase in the occurrence of drought in the study area while 48.1% explained that there has been an increase in temperature in their locality. About 21.8% indicated that they have experienced strong wind while 27.6% indicated that frost has occurred on occasional cases in the area. 53.2 percent talked about other climatic variables such as hailstorm has also been experienced in their locality. This implies that an average of the respondents has witnessed flooding on some occasions and almost all the respondents has also witnessed droughts. This means that when there is too much rainfall, this leads to flooding and erosion which then washes off the surface of the soil leading to surface run-off and loss of soil nutrients thereby leading to increased pests and diseases incidents loss in crop yield and low productivity. However, in times when there is low rainfall, temperature increases and leads to increase in the rate of evaporation in the soil thereby leading to drought, loss of nutrients in the soil and reduced crop yield. This is evident that drought is the most identified climatic variable that is changing and occurring in the study area. This result is in agreement with

other studies carried out by Shewmake (2018), reported in detail that change in climate is expected to increase the occurrence of adverse weather events such as droughts and floods especially in the Sub-Saharan Africa due to changes in rainfall pattern in the long run and changes in temperate regions. It also reported that a cross-sectional data survey was used in 2005 to detect that Limpopo Province has the highest occurrence of droughts in that year which has led to a negative impact on agricultural production. Low yield, poor crop performance, poor germination, ease of spread of diseases and ineffectiveness of agricultural chemicals due to delayed rainfall has amongst other factors been attributed to climate changes (Ayanwuyi et al. 2010).

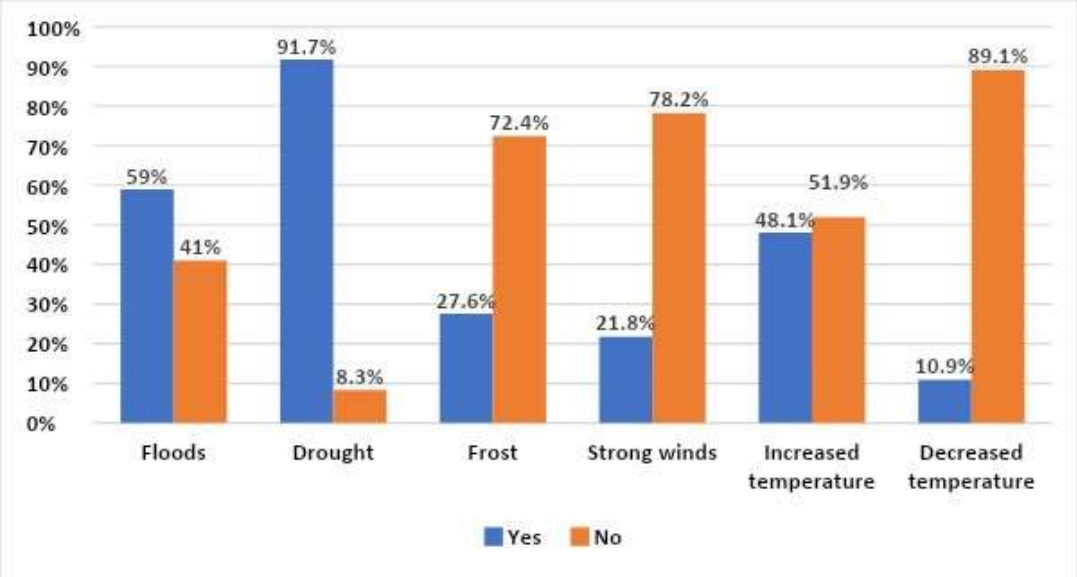

Figure 4.9: Farmers' experience with adverse climate condition (Source: Data used from survey, 2019)

4.3.13. Frequency distribution of participants according to climate change effects on crop productivity

This survey has revealed in Figure 4.10 that climate change impacts has really affected crop production in the study area. Majority of the farmers in the study area accounting for 91.7% of the respondents indicated that there has been a decrease in their level of production, 25% indicated that there has been an increase in their level of production, 50.6% indicated there was no change in their production level while 10.3% indicated there was no production at all because climate

change was affecting their farming activities. This implies that there is a decrease in crop production in the study area which will in turn lead to reduced food security, low income on crop yields and increase in poor level of livelihood in the study area. This result is consistent with other studies conducted by Cullis (2016) which reported its findings that due to relative increase in temperature across South Africa, crop production especially dry-land crops will be affected by changing conditions thereby leading to a decline in crop yield by 2050. Akinnagbe et al. (2014) also reported in his research findings that climate variabilities such as temperature, rainfall, carbon dioxide concentration in the atmosphere and extreme weather events affects yields of crops. On the contrary, 25% of the respondents reported that there was an increase in their production, this might suggest that the farmers have a superficial understanding on the entire climate change phenomenon.

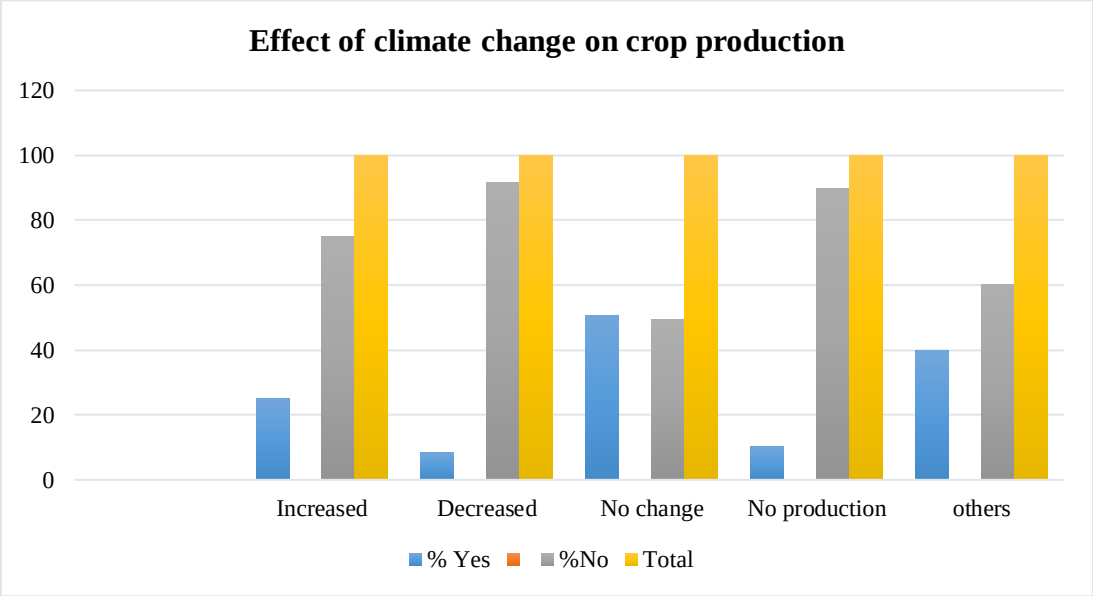

Figure 4.10: figure showing climate change effect on crop production (Source: Data from Survey, 2019)

4.3.14. Distribution of respondents based on climate change impacts on livelihood

From Figure 4.11, (52.6%) in the study area indicated that climate change impact has led to a significant increase in the socio-economic problems in their community while 47.4% explained that their socio-economic problems have not increased owing to climate change. Unemployment

has also increased in response to climate change as indicated by 63.5% of the respondents while 53.2% indicated that land under cultivation will decrease. The impact of climate change on employment and area under cultivation cannot be overemphasized. Studies have proved how climate changes are detrimental to production and thereby affecting employment especially in rural communities who wholly depends on agriculture (Ayanwuyi et al. 2010). Consequently, reduction of employment results in reduced income at household level. Fifty-nine percent of the respondents indicated that climate change has attributed to reduced income. The results are in line with the findings of Nhemachena et al. (2014) which alluded that climate changes have adverse effects on livelihoods.

Invariably, with reduced income, land under cultivation and increased unemployment, food insecurity is inevitable as most household will struggle to access food owing to lack of income (Assan 2018). How the respondents' food security has been affected by climate change is tabulated in Table 4.5.

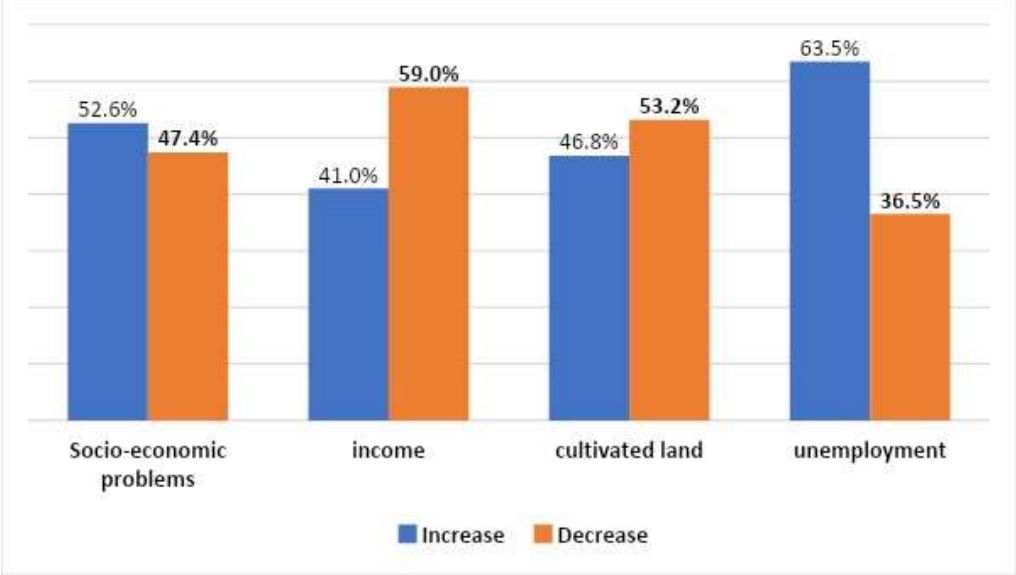

Figure 4.11: Impact of climate change on livelihood (Source: Data used from survey, 2019)

4.3.15. Distribution of respondents based on climate change impacts on agricultural production

Table 4.13 shows the responses of the farmers in the study area on how climate change impacts has affected their production. It showed that 67.9% of the respondents indicated that climate change impact has affected/ reduced the fertility of their farmlands while 32.1% indicated that its impacts has actually increased the fertility of their lands in one way or the other. 65.4% of them explained that climate change impacts have also led to an increase in crop diseases on their farms while 50% showed that their livestock production has drastically reduce due to the impact of climate change on their livestock. 62.2 percent also indicated among the crop farmers that there has been a decrease in their crop yield due to its impacts on their productivity. This implies that there has been decrease in crop yield in the study area over time due to reduced land fertility and increase in crop diseases which has affected the production. This might mean that food security is been threatened in the study area as there is not enough production due to climate change impacts. This is supported by a study conducted by Kumar et al. (2013) in India that climate change impact on agricultural productivity is evident of food grain and non-food grain productivity which in turn affects food security especially small-holder farming households. Masters et al. (2010) also explained in his study that by 2080 crop yields could decrease by 15%, agricultural production output could decrease by 20% in underdeveloped countries due to the effects of changes in climate while yield output is expected to decrease by 6% in developed countries.

Table 4.13: Distribution of climate change impact on agricultural production

Agricultural production variable	**Frequency**			
	Increase (%)		Decrease (%)	
Land fertility	50	32.1	106	67.9
Crop yield	59	37.8	97	62.2
Crop disease	102	65.4	54	34.6
Livestock production	78	50.0	78	50.0

Source: Data used from survey (2019)

4.3.16. Respondents' distribution based on impacts of climate change on food security

Participants gave explanations on how changes in climate have affected their food security, this is indicated in Table 4.14. 58.3 percent indicated that climate change impact has led to increase in food prices while 60.9% showed that it has led to scarcity of food. 87.8 percent indicated that climate change impact has led to lack of local market to sell their products while 12.2% stated that it has led to an increase in the availability of local markets for their produce. Most of the respondents 74.4% indicated that it has also led to decrease in employment rate. This finding suggests that climate change effects can lead to production problems in the long-run and seasonal low crop yields hence resulting to food insecurity in the study area. FAO (2008) report stated that climate change impacts will have an impact on human health, livelihood assets, food production and food security. Ahmad et al. (2011) also stated that changes in climate variables can affect the ability of a country to feed its people, this is because food security is dependent on the impacts of changes in climate.

Table 4.14: Impact of climate change on food security

Variable	Increase	Decrease
Food prices	58,3%	41,7%
Employment	25,6%	74,4%
Income	49,6%	50,6%
Food availability	39,1%	60,9%
Local market	12,2%	87,8%

Source: Data used from survey (2019)

4.4. Distribution of Respondents According to Farmers' Adaptation Measures

4.4.1. Distribution of respondents according to if they adapt to or cope with climate change

Figure 4.12 described the frequency at which the farmers in the study area adapted to changes in climate or how they cope with its impacts. 35.9% indicated that they could not cope with its climate change effects while 64.1% stated that they were able to adapt to climate change and its impacts. This might be due to many reasons. Those that did not cope might not have been aware that the climate is changing, lack of access to extension workers, lack of financial support or even lack of technical know-how might have led to the farmers not been able to cope with climate change. James et al. (2013) explained that factors that are important for farmers to be able to cope with climate change include access to higher education, access to financial support and extension services and experience in farming will also help the farmers to cope with climate change.

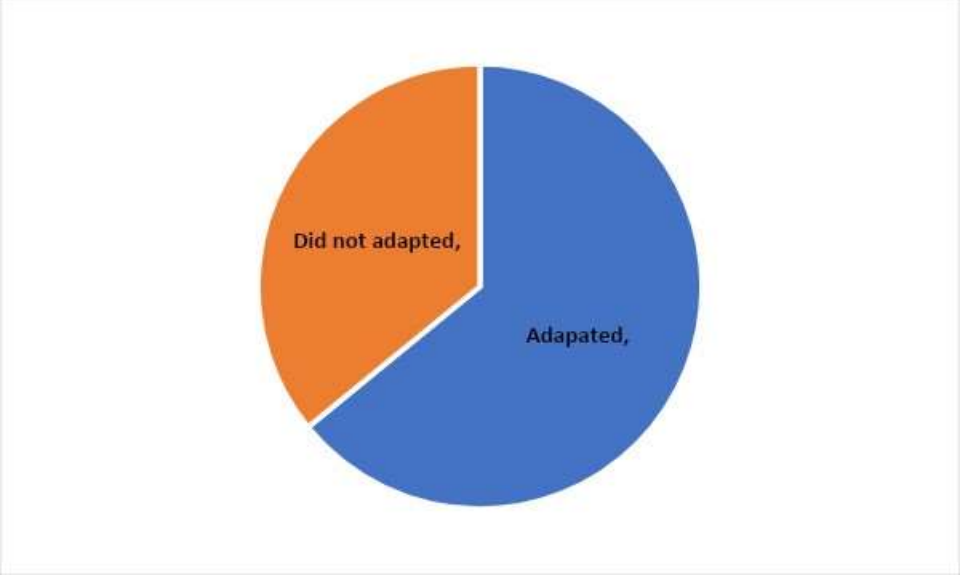

Figure 4.12: Frequency distribution according to climate change adaptation (Source: Data from Survey, 2019)

4.5 Empirical Results

4.5.1. Factors affecting farmers' decision to adapt to climate change

The factors that influence the farmers' decision to adapt to climate change were empirically identified using a binary logistic regression model. The farmers were asked if they had adapted

with climate change. The responses took values of 1 for the farmers who had adapted to climate change and 0 for farmers who had not adapted to climate change, thereby making the responses become the dependent variable. The proportion of the farmers who adapted against those who did not is represented in Figure 4.12. Most of the farmers indicated that they have adapted to climate changes while a few did not. Using the adaptation of farmers to climate change as a dependent variable, a binary logistic model was employed. The results of the binary model are presented below in Table 4.15.

Table 4.15: Factors affecting the farmers` decision to adapt to climate change

Variable	**Coefficient**	**Std Error**	**P> IzI**
Gender	-0,627461	0.5549164	0.258
Farming experience	0,1719967	0.34281	0.616
Access to information	0,227573	0.5363761	0.672
Land tenure system	-0,3946359	0.4771624	0.408
Source of income	-1,730177	0.7761248	0.026**
Education level	0,6390651	0.3544164	0.071*
Farm size	1,11794	0,2438736	0.000***
Main occupation	-1,634294	0.7806717	0.036**
Marital status	-0,4475633	0.3633004	0.218
Household size	-0,125006	0.2671302	0.640
Age	-0,4053699	0.4300395	0.346
Cons	-1,046681	1.08994	0.337

Number of Observation =156

LR chi2(11) =83,76

Prob > chi2 = 0,0000

Pseudo R2=0,4112

Log Likelihood = -59,959072

* = significant p-value <0.01; ** = significant p-value <0.05; *** = significant p-value <0.1

From Table 4.6, there is a statistically significant relationship (p-value <0.05) between source of income and climate change adaptation. The coefficient for source of income (-1.730177) suggests that respondents whose main source of livelihood (income) is farming are likely to have low rate of adaptability to climate change impacts at *ceteris paribus* as compared to their counterparts whose main source of income is not farming. This implies that farmers who takes part in off-farm income activities are more likely to overcome their financial constraints hence have the capacity to purchase good irrigation system as a means to adapt to changes in climate than those who only take part farming activities to enhance their livelihood. Households that have access to off-farm income are likely to adapt to climate change. This is in correlation with the study by Ojo and Baiyegunhi (2018), who found a positive relationship between household income and adoption of management practices.

The estimate of the coefficient of education level (0.6390651) is positive. The coefficient suggests, any other level of education that the farmer has is expected to increase the chances and ideas of the farmer to adapt to climate change. Education level is also statistically significant associated to climate change adaptation at p-value <0.1 level of significance with all other variables at constant. Therefore, in comparison to the farmers who have obtained tertiary level education, farmers who have obtained any other lower level of education including those who have no formal education are also likely to adapt to climate change. Education comes with easy understanding and openness to change. Previous studies have indicated that there is a positive relationship between education level and decision to adapt to climate changes (Anunrat *et al*., 2017; Jianjun *et al*., 2015).

There is a positive association between farm size and the adaptation to climate change adaptation as indicated by the coefficient, (1,11794). This implies that farmers who have larger farms are more likely to adapt to climate change. Farm size is also statistically significant at all level of significance holding other variables constant. Therefore, farmers whose farm size is more than 2 hectares are highly likely to adapt to climate change. The results of this study are in agreement with the results of a study by (Belay et al. 2017). Large farm size provides an opportunity for crop diversification and livestock enterprises thereby assisting with distributing risks associated with

unpredictable weather patterns. Therefore, large farm sizes are positively associated with climate change adaptation decisions (Belay et al. 2017).

At *ceteris paribus*, if the main occupation of the respondent is not farming, the less likely they are to adapt to climate changes as indicated by the coefficient (-1,634294). The association between main occupation and climate change adaptation is statistically significant at p-value <0.05. This therefore means that respondents who consider farming as their main occupation are more likely to adapt to climate changes than those who are part-time farmers.

There is a negative association between gender and climate change adaptation as indicated by the coefficient (-0,627461) *ceteris paribus*. This implies that female farmers are unlikely to take up adaptation measures compared to their male counterparts. However, the relationship is not statistically significant at any level of significance. A study conducted by Tibesigwa and Visser (2015) found that adaptation to climate changes is more in male-headed farm households than female-headed households. However, Ylipa *et al*., (2019) claim that females adapt more to climate changes than males as most men are based in cities while the women remain in the rural areas engaging in farming activities.

Farmers who have not had access to climate change information are also likely to adapt to climate changes unlike the farmers who had access to the information. This is as indicated by the positive coefficient (0,227573), at *ceteris paribus*. Although the association is in line with *apriori* expectations, the association is not statistically significant. It is expected that accessing information to climate change increases knowledge of the farmer about the implications of climate change thereby positively associated with climate change adaptation (Adesina et al. 1995; Luseno et al. 2003).

There is a negative association (-0,4053699) between age and climate change adaptation at *ceteris paribus*. This suggests that farmers who are above the age of 35 years are less likely to adapt to climate changes. However, the association is not statistically significant. Studies have shown that

older farmers grasp the concept of climate change faster as they are able to compare previous weather conditions with current ones hence being more open to change (Belay et al. 2017; Hisali et al. 2011).

4.6 Climate change adaptation strategies

Furthermore, the specific climate change adaptation measures the farmers employed were captured. Their perceptions on how the climate adaptation strategies are important to them and their perceptions on what drove them to adapt to climate change were also captured. The results are presented in this section. Table 4.16 shows the strategies that the farmers have been using to adapt to climate changes

Table 4.16: Climate change strategies adapted by the farmers

Climate change strategy	Percentage	Climate change strategy	Percentage
Crop diversification	14.1	Change the land area size	12.8
Multi-cropping	37.8	Increased use of irrigation system	40.4
Use of different planting dates	41.7	Increased water conservation	15.4
Practicing crop rotation	48.7	Finding off-farm jobs	4.5
Planting different crop Varieties	28.9	Use of drought tolerant varieties	23.1
Soil conservation techniques	41.0	Change of fertilizers and pesticides	30.8
Integrated farming system	18.6	Use of crop insurance	18.6
Crop-livestock shift	19.2	Changing farmland	19.2
Use of agricultural Subsidies	14.1	No adaptation strategies	9.0

Source: Survey Data (2019)

Table 4.16 shows the proportion of the respondents according to the adaptation strategies they adopted to or cope with climate change impacts. About 14% of the respondents indicated that they practiced crop diversification to adapt to climate change while 37.8% stated that they practiced multi-cropping, 41.7% used different planting dates, 48.7% practiced crop rotation while 28.9% planted different varieties of crops to cope with climate change on their farms. Forty one percent used soil conservation techniques while 18.6% practiced integrated farming system. Approximately 19% stated they practiced crop-livestock shift whilst 12.8% changed the area of land they used to farm, 40.4% indicated they practiced increased use of irrigation system, 15.4% used increased water conservation techniques. Only 4.5% find off-farm jobs to support themselves while 23.1% planted seeds that are drought-resistant so as to cope with climate change. About 31%, indicated that they change the type of fertilizers and pesticides they used on their various farms to cope with climate change whilst 18.6% have crop insurance to save themselves from the menace of climate change impacts. Some of the farmers 19.2% changed their farmland totally and moved to another so that the old one can rest and regain back its nutrients, 14.1% made use of agricultural subsidies while 9.0% indicated there was no perceived adaptation strategy, they followed in coping with climate change. This shows that almost average of the farmers practiced crop rotation, change of different planting dates, soil conservation and irrigation system on their farms to cope with climate change impact. This suggests that farmers in the study area still need to be sensitized on the different adaptation strategies that can be practiced to cope with climate change.

The farmers perceptions on how the strategies they adopted to cope with climate changes are important to crop production are summarized in Figure 4.13.

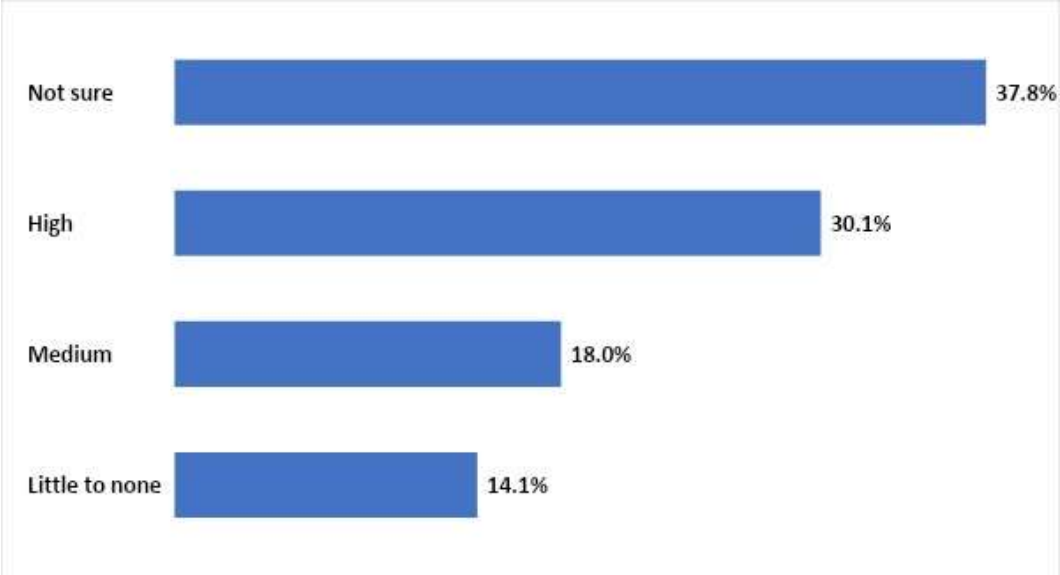

Figure 4.13: Perceptions of the farmers on the importance of climate change strategies (Source: Survey data, 2019)

A substantial proportion of the respondents, 37.8%, are not sure if the strategies they have adapted to cope with climate changes are of any importance to climate changes. This might suggest that the farmers do not have a clear knowledge of the climate change adaptation strategies and the entire climate change phenomenon. About 30% are of the opinion that that the various adaptation measures they used in coping with climate change are of high importance to crop production. Eighteen percent of the respondents perceive the climate change strategies of medium importance, whilst 14.1% perceive them of little to no importance to their crop production. A small proportion of the farmers, 4.5% believe that the climate change strategies are of no effect to crop productivity.

The farmers who indicated that they did not adapt to climate changes, whose proportion (39.5%) is shown in Figure 4.12 were asked to provide reasons for the nonadaptation. Their reasons are tabulated in Table 4.17.

Table 4.17: Reasons for not adapting to climate change

Reason	Yes	No
Lack of information	5.1%	94.9%
Lack of money	39.7%	60.3%
Not aware of climate changes	14.7%	85.3%
Lack of technical know-how	0.6%	99.4%
Not knowing what to do	1.9%	98.1%

Source: Survey Data (2019)

Lack of money (39.7%) and general lack of awareness of climate change (14.7%) are the most prominent reasons for not adapting to climate changes. About 5% of the respondents indicated that lack of information on climate change was the reason they did not take up any adaptation measure to cope with climate change.

4.7 Chapter Summary

In this chapter, the study results were presented, interpreted and discussed. The demographic characteristics of the respondents (farmers) were explained in detail and the adaptation strategies they adopted to cope with the impact of climate change. As well, the factors affecting farmers' decision to adapt to climate change were presented and discussed.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the findings of the research and presents some conclusions and recommendations. Crop production is an important part of the agricultural sector and plays a huge role in the economy of South Africa. It particularly plays a big role in the Limpopo Province of South Africa as it provides various job opportunities to the communities especially in the rural area. Because majority of these rural communities depends on agricultural activities for livelihood, it is evident that they are mostly affected with the impacts of changes in climate and its variabilities, hence the need for proper knowledge of the adaptation strategies these farmers can adopt to help them cope with changes in climate. However, this study investigated the impacts of changes in climate and its variability at the farm level by indicating the determinant factors that affects the farmers' adaptation to climate change.

5.2 Summary

Changing climate has been known to affect agricultural production in negative ways. Because of these effects, it is important for farmers to adopt proper adaptation strategies so as to help minimize these negative impacts of changes in climate. The study examined the determinant factors of climate change adaptation measures among crop farmers in the Limpopo Province of South Africa. The specific objectives of the study were;

- To determine the socio-economic characteristics of the respondents in the study area.
- To identify the factors influencing the farmers' decision to adapt to the negative impact of climate change.
- To assess the farmers' perception towards climate change.
- To assess the specific climate change adaptation strategies the farmers have adopted to help cope with the negative impacts of climate change.

5.2.1 Summary of major findings

Farmers' demographic characteristics were examined in order to investigate the factors that affect their decisions to adapt to the negative impact of climate change, to understand their perceptions towards climate change and their level of awareness about the phenomenon. A Cronbach alpha was used to test the reliability and validity of the data that was gathered. It was discovered that farming is the major occupation with 73.7% of the participants in the study area and their major source of income is also farming (75.6%).

A binary logistic regression model was used to identify the factors that influence the farmers' decision to adapt to climate change. From the results, it was discovered that the source of income influenced climate change adaptation. Adaptation is an important measure(s) that must be taken into consideration by farmers to achieve their farming goals so as to improve their livelihood, food security and reduction in the negative impacts of changes in climate. Results identified that farmers whose main source of income is farming are likely not to adopt any adaption measures to climate change compared to others who has other source of income. The results also showed that the level of education of the farmers increased their chances to adapt to climate change. Farmers who have large farm size that is more than 2 hectares are also likely to adapt to the negative impacts of climate change. Also, farmers who choose farming as their major occupation are more likely to adapt to climate change than those who see farming as part time job.

The study also identified the adaptation measures those farmers employed to adapt to the negative impacts of climate change in the study area. It was identified that most of them practiced crop rotation, irrigation system, use of different planting dates and the use of soil conversation techniques to cope with climate change impacts.

5.3 Conclusions

Many studies have shown that climate change has been a major problem in South Africa and there are several discussions on how to deal with this problem. However, these problems cannot be solved when the people especially the farmers do not understand or perceive climate change and identify how it is affecting their productivity and society at large. This is why this study was conducted to identify how farmers have perceived climate change, the impacts it has on their crop production, examine the factors that affected their decisions to adapt or not to climate change, and also identify the adaptation strategies that they adopt to cope with or adapt to these changes.

This study concluded that majority of the farmers perceived that temperature and rainfall are the most common changing variables they have witnessed. Temperature is increasing while rainfall is reducing. The findings also revealed some factors that is influencing their decisions to adapt or not which includes source of income, main occupation of the farmer and farm size. The study also identified the adaptation strategies used by the farmers who decided to do something about these changes. It was concluded that majority of the farmers practiced crop rotation, soil conservation techniques, use of different planting dates and irrigation system to adapt to changes in climate.

5.4. Recommendations

Policy recommendations were suggested based on the research findings and can be put into consideration by the government in the province and other sectors involved in matters relating to climate change. These policies aim to improve the determinant factors for crop farmers in the study area and South Africa as a whole to make use of proper adaptation measures to changes in climate.

- Government needs to put in place policies that will support research and developments to give better technologies to farmers to help them adapt to the negative impacts of climate change and there should be proper information channel that can help results from researches carried out to reach the farmers.
- Proper education and training programs should be put in place to enhance for better information to the farmers to help them have a proper and better understanding of the

phenomenon of climate change and the adaptation strategies they can employ to help cope with the negative impacts of climate change.

- Government as well as private institutions should help provide better ways of how farmers can gain access to improved climate information forecasting and provide adequate extension services to them. These will help them to know more about the changing climate and understand better the technical know-how of how to use the adaptation measures to help them cope with climate change impacts.
- Certain adaptation measures should be subsidized for farmers especially those employed at the farm-level such as irrigation systems, soil conservation techniques to mention a few as most small-scale farmers cannot afford these improved technology techniques to help them improve their adaptive capacity. More incentives should also be provided to them such as new and improved seedlings, pesticides and insecticides to help fight infestations on the farms and crop insurances.
- Proper climate change awareness programs should be put in place for farmers, this is to educate them about climate change because the study discovered that information on climate change and awareness was a major problem for farmers not to employ adaptation measures to cope with its impacts. Therefore, it is important for government especially at the provincial level in the study area to disseminate information about this menace to the farmers and how it can affect their productivity and livelihood if proper adaptation measures are not taken.
- Farmers should have an open-mind to new technologies, gather knowledge on climate change and tools that can be used in production, capacity building and management practices that can help them to cope with or mitigate the changes in climate.
- Farmers should also start documenting their yield results so they can have proper information on the changes in yield over the years, this will help them to be able to understand how changes in climate has affected their productivity and make proper decisions about adaptation or mitigation strategies.

5.5 Suggestions for further research

As climate continue to heat up and its impacts is growing persistently and severe across the world, farmers and farm communities across the world will be more challenged as they would not be spared from the damage the change in climate will cause to their productivity. Hence, there is need for more research to be done by the scientific community to help farmers fight or cope with these climate change impacts.

- The scientific community can contribute to help fight this menace through research that improves the knowledge on the causes and outcome of changes in climate and also make important contribution to decision makers at local, regional, national and international levels.
- More research should be done on insurance policies for farmers. How more farmers especially from the rural communities and small holder farmers can have access to these insurance policies so as to save them or give them relief from the looming disasters ahead in the years to come.
- More research should also be done to create more awareness on diverse agroecosystems so as to help farmers reduce their dependence on fertilizers and pesticides usage on their farms which also has adverse effects on their productivity.
- More research should be done on developing new practices and how to improve on the training of farmers on these new practices and opportunities that helps build strong adaptive capacity.
- Research should also be done to develop improved crop varieties; livestock breeds and farm management practices that will be specifically designed to help farmers adapt to or cope with the evolving changing in climate and its variabilities and the determinants of these adaptation strategies adopted by the farmers should be understudied at the grass root level to help understand climate changes and how it's impacts can be tackled.

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APPENDIX (QUESTIONNAIRE)

DEPARTMENT OF AGRICUTURE AND ANIMAL HEALTH

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

UNIVERSITY OF SOUTH AFRICA

DETERMINANTS OF CLIMATE CHANGE ADAPTATION MEASURES AMONG CROP FARMERS IN LIMPOPO PROVINCE OF SOUTH AFRICA.

NOTE: Information given by the respondent is strictly confidential and will only be used for the purpose of this research. Information given will not be disclosed to anyone, only when your consent is given.

Fill in your answers in the spaces provided

Interviewer's Name:

Date:

Questionnaire number:

District Municipality:

Local Municipality:

Ward:

SECTION A:

SOCIO- ECONOMIC CHARACTERISTICS OF THE RESPONDENT (FARMER)

1. Age:

<18years	19-35years	36-45years	46-55years	and 56years above

2. Gender: Male [ ] Female [ ]

3. Marital Status:

Single	Married	Divorced	Widowed	Separated	Others (specify)

4. Educational level: Please tick the appropriate one

University	College	Advanced level	Completed High School	Some High School	Completed primary Sch.
Some primary Sch.	Completed vocational training	Some vocational training	Adult Education	No Formal Education	

5. Household Size:
6. What is your major Occupation?

Farming	Employed	Trading	Self Employed	Business	Pensioner	No Occupation

7. Is Farming your major source of income? YES [ ] NO [ ]

8. CROPS CULTIVATED

Which crop(s) do you plant? Indicate by ticking the appropriate one accordingly

Avocado [ ] Tomatoes [ ] Both [ ]

9. What is your main reason for planting this crop(s)?

Reason	Response
For household consumption	
Personal consumption but small quantity is sold out	
Large-scale production (commercial purposes	
Industrial Use	
Others, please indicate	

10. CHARACTERISTICS OF LAND USE

Land tenure system

Individual owner	Communal	Lease (Permission to own)	Renting	Others (indicate)

11. Farm owner

Private owned	Family members	Group of farmers	Company owned	Owned by trustee	Others (indicate)

12. Farm manager

Individual farmer	Member(s) of the family	Group of farmers	Company owned	Managed by trustee	Others (indicate)

13. Size of cultivated land

Less than1hectare	1-5 hectares	6-10 hectares	11-15 hectares	16-20 hectares	More than 20 hectares

SECTION B:

INFORMATION ABOUT CHANGES IN CLIMATE AND ITS AWARENESS; PLEASE FILL IN THE APPRPROPRIATE SPACE BELOW.

1. Do you get any information about changes in climate? YES ( ) NO ( )
2. Has any awareness been made on changes in climate in your community?

YES ( ) NO ( )

3. Do you have a personal awareness that the climate is changing? YES ( ) NO ( )

NOTE: If "NO" is your answer, please omit question 4 and 5 and go to question 6.

4. If "YES" is your answer in question 3, do you agree with the following statement? Use the following code for the response to the question
   1= Strongly agree
   2= Agree
   3= Undecided
   4= Disagree
   5= Strongly disagree

Statement	Response
Activities done by human beings contribute to the impacts of changes in climate	
Increased frequency of droughts is as a result of the effects of changes in climate	
Increased occurrence of floods is as a result of the effects of changes in climate	
Cutting down of trees and uncontrolled burning of forests contributes to the effects of climate change	
Fume exhaust from cars (CO_2) also contribute to climate change	
Gas discharge (Emissions) from Industries contribute to climate change	
Human beings are responsible for implementing the mitigation and adaptation strategies been put in place on climate change	
Planting of trees (Afforestation) contribute positively in helping to fight against climate change	
Rainfall distribution is evident in some areas than in other places	

5. If "YES" is your answer in question 3, how did you get to know about climate change?
   Use the following code for your answer
   1= Yes
   2= No

Own observation	
Learnt from formal schooling	
Learnt from non-formal schooling (adult education)	
Extension service system	
Read about it from the media (newspapers, magazines, television, radio, newsletter, internets, etc.	
From other people	
Others	

6. Does the information you get make any difference in your level of production?

Yes	No

SECTION C:
FARMERS' OBSERVATION ON CLIMATE CHANGE

1. Have you observed any climatic changes?

Yes	No

2. If "YES" is your answer, which of the climatic variables is changing?

Temperature	Rainfall	Drought	Strong wind	No wind	Others (Specify)

3. How do you perceive changes in rainfall in the long term?

Increased rainfall	
Decreased rainfall	
No changes in rainfall have been observed	
Temperature has not changed	
Others (Specify)	

4. How do you perceive changes in temperature in the long term?

Increased temperature	
Decreased temperature	
No changes in temperature have been observed	
Temperature has not changed	
Others (Specify)	

5. How do you perceive changes in wind in the long term?

Increased whirl wind	

Decreased whirl wind	
Whirl wind has not changed	
No changes in whirl wind have been observed	
Others (indicate)	

6. Please indicate which of the stated below you have experienced in your community

Flood	Drought	Frost	Strong wind	Temperature increase	Temperature decrease	Others (indicate)

7. Indicate how changes in climate affected your crop(s) productivity

	Response	Code
Increase in productivity		1
Decreased production		2
No changes in productivity		3
No yield at all		4
Others (indicate)		5

8. Specify the effects of changes in climate on your livelihood

	Response	Code
Socio-economic problems have been on the increase		1
There has been decrease in socio-economic problems		2
Increased income		3
Decreased income		4
Farms cultivated were increased		5
Farms cultivated decreased		6
Increased unemployment rate		7
Decreased unemployment rate		8
Others (indicate)		9

9. Describe how the changes in climate has affected your crop production

	Response	Code

Fertility of farmland increased		1
Fertility of farmland decreased		2
Crop yield increased		3
Crop yield decreased		4
Disease infestation on crops increased		5
Disease infestation on crops decreased		6
Increased production of livestock		7
Decreased production of livestock		8
Others (indicate)		9

10. Effects of changes in climate on security of food in your community

	Response	Code
High prices of food		1
Decrease in prices of food		2
Increased employment		3
Decreased employment		4
Increased income		5

Decreased income		6
Scarcity of food		7
Availability of food		8
Lack of local markets for selling		9
Others (indicate)		10

SECTION D:

FARMERS' ADAPTATION MEASURES

1. What is the duration of you been a farmer?

Not applicable	< 2years	2-5years	6-10years	11-15years	16-20years	> 20years

2. Did you adapt to or cope with climate change?

Yes	No

3. Specify the adaptation strategies/ options you adopted

	Response	Code
Practicing crop diversification		1
Plant different crops (multi-cropping)		2
Use of different planting dates		3
Practicing crop rotation		4
Plant different varieties of crops		5

Soil conservation techniques		6
Integrated farming system		7
Change from crop production to livestock production		8
Change the amount of land		9
Increased use of Irrigation system		10
Increased water conservation		11
Find off-farm jobs		12
Use of drought-tolerant varieties		13
Changes in the type and amount of fertilizers, pesticides and chemicals used		14
Use of crop insurance		15
Move to a different farm land		16
Use of Agricultural subsidies		17
No perceived adaptation options		18
Others (specify)		19

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

5. How are the adaptation measures taken of any importance to your productivity?

	Response	Code
High importance		1
Low importance		2
Medium importance		3
No importance		4

6. If you did not adapt, please specify your reasons for not adopting any adaptation measures

	Response	Code
Information was not made available		1
Lack of money		2
Not aware of changes in climate		3

Lack of technical abilities to be used		4
Distance to weather stations		5
Distance to input markets		6
Do not know what to do		7
Differences in Agro-ecological zone		8
Others (indicate)		9
Not applicable		10

Thank you for your time

THIS QUESTIONNAIRE IS COMPILED BY OGUNSOLA MARY TOSIN UNIVERSITY OF SOUTH AFRICA.