CLIMATE CHANGE AWARENESS: A CASE STUDY OF SMALL SCALE MAIZE FARMERS IN MPUMALANGA PROVINCE, SOUTH AFRICA

by

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DEDICATION

This thesis is dedicated to my Best Friend, my Comforter who always gives me inspiration and insight. It is also dedicated to Mrs E.A Oduniyi, for her prayers, moral advice and emotional support. I cannot but mention Anthonia Oduniyi and Oluwademilade Oduniyi. I adore you all.

DECLARATION

I, Oluwaseun Samuel Oduniyi, declare that "CLIMATE CHANGE AWARENESS: A CASE STUDY OF SMALL-SCALE MAIZE FARMERS IN MPUMALANGA PROVINCE, SOUTH AFRICA" is my own work and all the sources that I have used or quoted have been indicated and acknowledged by means of complete references. The work has not been submitted before for any degree or examination at any other university.

Signature …………………. Date ……………………

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ABSTRACT

This study was conducted in the Nkangala district, in the province of Mpumalanga in South Africa. This province remains the largest forestry production region in South Africa. The majority of people living in Mpumalanga are farmers and they have contributed immensely to promote food security. The objective of the study was to determine the level of climate change awareness among small scale maize producers in Mpumalanga province. Random sampling technique was used to select two hundred and fifty one (251) farmers to be interviewed. A pre-tested questionnaire was administered to maize farmers, focusing on matters relating to climate change awareness in maize production. Data was captured and analysed using software package for social science (SPSS version 20of 2012). Descriptive statistics were applied to analyse and describe the data. Logistic regression analysis followed to demonstrate the significance of the independent variables on climate change awareness. The results of the analysis indicated that the information received and the size of the farm had an impact on climate change awareness in the area of study. It was therefore recommended that the majority of farmers in Mpumalanga needed to be made aware of climate change in order to assist them to build the adaptive capacity, increase resilience and reduce vulnerability. Information on climate change awareness should be disseminated well to ensure that it will attract the attention of the farmers.

Keywords: *climate change awareness, Mpumalanga province of South Africa, small-scale farmers, maize production, logistic regression analysis*

Table of Contents

List of Tables

List of Figures

LIST OF ACRONYMS

ACTSA	Association of Corporate Treasurers of Southern Africa
AMCEN	African Ministerial Conference on the Environment
AMSA	Arctic Marine Shipping Assessment
BFAP	Bureau for Food and Agricultural Policy
CCSP	Climate Change Science Program
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs and Tourism.
DWAF	Department of Water and Environmental Affairs
EIA	Environmental impact assessment
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHGs	Greenhouse Gas Emissions
ICPAC	Climate Prediction and Applications Centre
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IIRR	International Institute of Rural Reconstruction
IITA	International Institute of Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change

LIM	Land Information Memorandum
MDGs	Millennium Development Goals
MTENR (Zambia)	Ministry of Tourism, Environment and Natural Resources
NAPA	National Adaptation Programmes of Action
NCAR	National Centre for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
SADC	Southern African Development Community
SAGL	South Africa Grain Laboratory
SAI	South Africa Info
SPSS	Statistical Package for the Social Sciences
StatsSA	Statistics South Africa
TAR	Third Assessment Report
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WHO	World Health Organization
WMO	World Meteorological Organization

WWF	World Water Forum

CHAPTER 1

INTRODUCTION

1.1 Background

Climate change is one of the most important environmental challenges facing the world today. According to Hougton (2002) climate change is possibly the greatest environmental challenge facing the world this century. This is supported by the spate of conferences, campaigns, reports and research work on climate change over the past 20 years (Agenda 21 of Rio declaration, 1992; IPCC, 2001; Copenhagen, 2009) to mention a few. Presently, there is widespread consensus in the scientific community and even among farmers that climate change is a reality and that we are already experiencing its impact.

The impact of climate change awareness varies globally. The problem of climate change is becoming more threatening to sustainable economic development and the totality of human existence (Adejuwon, 2004). The developing world faces greater challenges than the developed world, both in terms of the impact of climate change and the capacity to respond to it. In addition, small-scale farmers still suffer the most because of their dependence on rain-fed agriculture, rising temperatures, low adaptive capacity, high dependence on natural resources, inability to detect the occurrence of extreme hydrological and meteorological events due to low technology adoption, limited infrastructure, illiteracy, lack of skills, level of awareness and lack of capacity to diversify (Kurukulasuriya & Mendelsohn, 2006b).

Several definitions of climate change are put forward by various scholars. The Intergovernmental Panel on Climate Change (IPCC), define the concept *climate change* as the natural cycles of weather patterns on earth resulting from changes in the amount of heat received from the sun. Climate goes through warm and cold periods, taking hundreds of years to complete one cycle. According to the IPCC (2001) these changes affect the temperature which also influences the rainfall. Plants and animals are able to adapt to a changing climate provided that these changes take place over hundreds of years. Unfortunately, human activity is currently causing the climate to change very fast. Climate change models predict that the average air temperature over South Africa will rise by an estimated 2°C over the next 100 years (Kruger & Shongwe, 2004). Plants and animals may not be able to adapt themselves as quickly to "rapid" climate change as humans can, and therefore the whole ecosystem is in danger (Madeleine, 2007).

The United Nations Framework Convention on Climate Change (UNFCCC, 2007) defined climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. According to the United States Environmental Protection Agency (EPA, 2004), climate change is referred to as any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change might result from natural factors and processes or from human activities and this change calls for a knowledgeable response from all countries in order for it to be effectively addressed. Climate change refers to a change which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over comparable time periods (UNFCC, 1992). The UNFCCC (2009) refers to climate change as natural variations which can be directly or indirectly connected to human activities and observed over a longer time period.

The IPCC´s fourth assessment report describes a trend of warming for Africa that is faster than the global average, showing that climate change is already a reality. Temperature in Africa has risen by 0.7°C during the 20th century and a 0.2 to 0.5°C temperature increase per decade is predicted while precipitation patterns vary considerably. Changes in frequency, intensity and predictability of rain are some of the most severe consequences of climate change for East Africa. According to the IPCC (2007) by 2020 crop yields depending on rain would decrease by up to 50 percent. Poor countries are extremely vulnerable to climate change and people in East Africa are dependent on marginalized natural resources for their survival, yields are already amidst the lowest in the world (IPCC, 2007). Therefore Africa cannot afford to lose yields to climate change.

Research shows that the SADC region is experiencing increasing frequency of hot days and decreasing frequency of extremely cold days. Extreme weather events, notably flood, drought and tropical storms are also expected to increase in frequency and intensity across the continent (IPCC, 2007). These projections are consistent with recent climatic trends in southern Africa, including Zimbabwe. Zimbabwe is particularly vulnerable due to its heavy dependence on rain-fed agriculture and climate sensitive resources (Charity *et al.,* 2013). A recent study shows that, from this period up to the year 2080, Zimbabwe will face a general decrease in reliability and predictability of rainfall patterns while temperatures are expected to rise by 2°C (Bohle *et al.,* 1994).

Climate change poses a drastic threat on Zimbabwe's agricultural industry that has continued to suffer from natural disasters and droughts recurrently (Charity *et al.,* 2013). Global warming has caused an increase in the average temperatures resulting in the shifting of the traditional farming seasons and agro-ecological zones. According to the Zimbabwe Department of Meteorological Services, Zimbabwe has increasingly seen more hot days between 1950 and 1990 (UNEP/GRIDA, 2002). An increase in average temperatures by 2°C will likely cause a decrease of Zimbabwe's wetlands from 9 percent to 2.5 percent and a 4°C increase would reduce the summer water-surplus zones to less than 2 percent (Bohle *et al.,* 1994). This change in temperatures will affect the agricultural production, particularly for crop yields. An increase temperature of 4 °C in Zimbabwe will decline maize yield by 20 percent in the north-east, and 27 percent in the south-east region, bordering Mozambique (Magadza, 1994).

Over the past several decades, evidence of human influences on climate change has become increasingly clear and compelling. There is indisputable evidence that human activities such as electricity production and transportation are adding to the concentrations of greenhouse gases (GHGs) that are already naturally present in the atmosphere. These heat-trapping gases are now at record-high levels in the atmosphere compared to the recent and distant past. Warming of the climate system is well-documented, evident from increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels. The build-up of GHGs in the atmosphere is likely the cause of most of the recently observed increase in average temperatures, and contributes to other climate changes (EPA, 2010).

People experience different problems related to climate change such as flood disaster, late onset of rains and early cessation of rainfall, reoccurring incidence of drought, increasing temperature, reduce river flow, declining water table, loss of some plants and animal species and the outbreak of some climate-related diseases. People's ignorance, especially as a result of the low literacy level, causes them to engage in activities that contribute to the problem of climate change. Much can be done at the individual, legislative (through government policies), and technological levels (Igwebuike *et al.,* 2009). There is urgent need for a better understanding of the changing climate pattern and how they affect extreme weather events (Tompkins, 2003 cited in Mba, 2009). Adequate knowledge and awareness of the effects of climate change will help make communities to join forces in reducing the vulnerability of societies to climate-related risks now and in the future.

The word awareness means to be conscious. To be highly conscious or the use the sum of all abilities, permit us to respect the basic rights of existence in every situation**.** Climate change awareness is being conscious of our changing environment. Climate change is an emerging issue in developing countries which are more concerned with, among others, poverty alleviation and food insecurity. There is very little awareness about climate change in the developing countries (IPCC, 1996). In order to achieve better crop production and food security, farmers need to be made aware of climate change. This awareness forms part of this case study of small-scale maize farmers in Mpumalanga, South Africa.

1.2. Problem statement

The IPCC (2001) indicated that climate change would have both positive and negative effects, but the adverse effects would predominate with greater rates of climate change. Based on research studies, it is estimated that farming, which is mainly supported by rain, provides employment to over 70 percent of the labour force in Africa. In South Africa, between 1960 and 2003, the mean temperature increased by 0.13°C (Kruger & Shongwe 2004), and mean rainfall is expected to decrease by 5 to 10 percent within the next 50 years (Hewitson 1999; Durand 2006). The expected reduction in rainfall will have a significant impact on South Africa's agriculture because a large portion of the country is semi-arid. The mean annual rainfall is 464 millimetres, which is low compared to the world average of 857 millimetres (BFAP, 2007).

Maize constitutes about 70 percent of grain production and covers about 60 percent of the cropping area in South Africa. Maize is a summer crop, mostly grown in semi-arid regions of the country, and is highly susceptible to changes in precipitation and temperature (Durand 2006; Benhin 2006). Although the maize plant is quite hardy and adaptable to harsh conditions, a drier or warmer climate and lower precipitation could have detrimental effects on its yield (BFAP, 2007). In addition, maize is the staple food in southern Africa, and maize production in the country constitutes about 50 percent of the output within the Southern African Development Community (SADC) region (Durand, 2006). Consequently, maize is one of the key drivers of food inflation in South Africa (BFAP, 2007). A considerable number of studies have been conducted to investigate the impact of climate change on yields of grain crops such as maize under controlled experiments (e.g. Du Toit *et al.,* 2002; *Kiker et al.,* 2002; Durand, 2006).

Agriculture is the backbone of South Africa's economy (Mandleni, 2011). It is one of the major occupations in Mpumalanga. Over the years, there has been incidences of climate change in Mpumalanga such as fire outbreaks, floods, excessive temperatures and rainfall. This had a negative impact on farm production and thus, reduced the level of farmers' living. The farmers need to be made aware about climate change in order to be able and understand what climate change is. This study is intended to establish climate change awareness among small-scale maize farmers.

The environmental and social consequences of climate change include:

(*a*) Putting livelihoods and food production at serious risks.

(b) Changes in the rainfall pattern greatly affect vegetation and agriculture.

(*c*) Climate change requires the development of natural resource management strategies to ensure the sustainable use of soils and water, halt biodiversity decline and deal with emerging issues such as the growing demand for renewable energy which, as a result, add more to cost of production thereby increasing food production.

A situation, in which farmers are aware of climate change, enables the farmer to adopt some measure of techniques to adapt to cope with climate change and also to help improve farm productivity. However, unaware farmers are not likely to cope with the change, thus, brings low productivity in farm production. Therefore, there is a need for farmers to be aware of climate change for better yields and improved productivity.

1.3 Research Aim

The aim of the study is to determine climate change awareness among small-scale maize farmers.

Research objectives are to:

- *(a)* Determine the level of awareness of small-scale maize farmers about climate change.
- *(b)* Compare the level of production scale between the farmers who are aware and the farmers who are not aware of climate change.
- *(c)* Find out which factors influence the level of farmers' awareness about climate change.

1.4 Significance of the study

Prevailing problems associated with changes in weather patterns caused by climate change provide sufficient reason to investigate whether small-scale maize farmers are aware of the climate change. A report from the South Africa Grain Laboratory (SAGL 2006) indicated that Mpumalanga produced 25 percent of the total commercial maize production in South Africa; 62 percent being white maize and 38 percent yellow maize. According to SAGL (2006) Mpumalanga is the second province producing maize commercially in South Africa making the province an important contributor to the country's total maize production. The findings obtained after carrying out this study should enable small-scale maize farmers in the study area to understand better the concept of climate change. Policy makers may also use the recommendation from the study to advise farmers about climate change effects and practices required to reduce its effects.

1.5 Limitations of the study

The research was limited in some aspects for particular reasons. The questionnaires used for data collection were prepared in English and most of the farmers were illiterate. Therefore interpreters had to be used to translate the questions into local languages in order for respondents to answer the questions, and to help filling out of the questionnaires. Another limitation is that some farmers could not really provide accurate answers to the questions regarding observation of climate change over the years.

1.6 Summary

This chapter provided the background to climate change as an important environmental matter affecting the nation at large today. An overview of different definitions by different scholars on climate change awareness was provided. It also provided the motivation for the study as well as the objectives. The significance of the study was pointed out and the limitations of the study provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Climate change, as phenomenon, is a reality and has been experienced across the entire globe. This chapter reflects on concepts and an understanding of climate change as an average pattern of weather over the long term. It also highlights the causes and the consequences of climate change. Climate change has been perceived in terms of extreme heat and flood, droughts and heavy rains, declining rainfall patterns, and rise in sea level. All these factors have a great impact on agriculture. The impacts are negative, and evident in food production and agriculture, health, water resources, ecosystem, shelter, vulnerable populations and national security. It further explains the future climate change in the study area and the level of awareness in many countries in Africa.

2.2 The climate change concept

Climate is the average pattern of weather over the long term. Climate change is not new and there is no doubt that the weather is growing warmer currently; indications of that change are evident around us. The study of how human activity affects the earth's climate. According to the IPCC (2007) the scientific community widely agreed that climate change is already a reality. The study of climate change cuts across many fields, which includes geology, meteorology, and even oceanography. The United States Environmental Protection Agency (EPA, 2010) referred to climate change as any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Over the past century, surface temperatures have risen, and associated impacts on physical and biological systems are increasingly being observed (PRC, 2007). Climate change will bring about gradual shifts such as sea level rise, movement of climatic zones due to increased temperatures, and changes in precipitation patterns (Wang *et al.,* 2010).

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

2.2.1 Observations about climate change

Research shows that the earth has become warmer during the previous century. The Intergovernmental Panel on Climate Change (IPCC, 2001) reports that the average surface temperature of the earth has increased during the 20th century by about 0.6°C ± 0.2°C. (The ± 0.2°C means that the increase might be as small as 0.4 °C or as great as 0.8°C). The IPCC (2001) further reported that it is warmer today around the world than at any time during the past 1000 years. Extreme weather events are now on the rise worldwide and are more likely to happen in the future (Easterling *et al.,* 2000). Climate change is perceived to be extreme temperature increases from time to time.

2.2.1.1 The international perspective on climate change

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

In North America, Mexico, like many developing countries, has the potential to be vulnerable to economic damages because of global climate change (Thornton *et al.,* 2009). Furthermore, the presence of large-scale poverty and a highly skewed income distribution exacerbates the situation and increases the vulnerability of certain areas to weather-related issues. According to Liverman and O'Brien (1991), Mexico is particularly prone to suffer at least two different types of these events such as droughts and hurricanes. The reason lies on the fact that Mexico is a developing country and most developing countries majorly base their economic activities on agriculture. According to Hazard Management Unit of World Bank (2004), a study indicated that Mexico is ranked 32 among the 60 countries affected by potential hazards such as earthquakes, volcano eruptions, floods, droughts and clones, and Mexico is predicted to be likely to face repeated disaster and repeated losses.

In Europe, Anderson and Bausch (2006) draw a link between climate change and weather disasters. Weather disasters were in the form of rising average temperatures since 1900. The magnitude of the rise in mean temperatures and the existence of severe extremes were inconsistent with the natural cycles. They were consistent with influence on human induced GHGs. More examples were intense precipitation and increased droughts and hurricanes. These phenomena occur in many European countries as a result of climate change.

2.2.1.2 Climate change based on continental perspective

Africa is one of the most vulnerable continents to climate change. According to Boko *et al.* (2007) climate change and climate variability is a situation aggravated by the interaction of “multiple stresses”, occurring at various levels. This situation is further worsened by its poor state of economic development and low adaptive capacity. Africa’s major economic sectors are vulnerable to current climate sensitivity, with huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts (IPCC, 2007).

Boko *et al.* (2007) indicate that agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability. A number of countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will most likely reduce the length of the growing season as well as force large regions of marginal agriculture out of production (IPCC, 2007). Projected reductions in yield in some countries could be as much as 50 percent by 2020, and crop net revenues could fall by as much as 90 percent by 2100, with small-scale farmers being the most affected. This could adversely affect food security on the Africa continent.

Water shortage is also associated with climate change. Climate change will aggravate water shortage which some countries already face, while other countries without water stress now will become at risk in the future (IPCC, 2007). Climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa. Even without climate change, several countries in Africa, particularly in northern Africa, will exceed the limits of their economically usable land-based water resources before 2025 (Boko *et al.,* 2007).

Climate change is also reported to alter the community of living organisms. According to the IPCC (2001) changes in a variety of ecosystems are already being detected, particularly in southern African ecosystems, at a faster rate than anticipated. Climate change and its interaction with human drivers such as deforestation and forest fires, are a threat to ecosystems (Muriuki *et al.,* 2005). Changes in grasslands and marine ecosystems are also noticeable. It is estimated that, by the 2080s, the proportion of arid and semi-arid land in Africa is likely to increase by 5 to 8 percent (Parry *et al.,* 2004). However, this implies that climate change can have broad effects on biodiversity.

The climate of the African continent is controlled by complex maritime and terrestrial interactions that produce a variety of climates across a range of regions, for example from the humid tropics to the hyper-arid Sahara (Christensen *et al.,* 2007). Climate exerts a significant control on the day-to-day economic development of Africa, particularly in the agricultural and water-resources sectors, at regional, local and household scales (IPCC, 2007). Since the IPCC Third Assessment Report, Climate Change 2001 (TAR), observed temperatures have indicated a greater warming trend since the 1960s. Although these trends seem to be consistent over the continent, the changes are not always uniform. For instance, decadal warming rates of 0.29°C in the African tropical forests (Malhi & Wright, 2004) and 0.1 to 0.3°C in South Africa (Kruger & Shongwe, 2004) have been observed.

Climate change can also be observed in the form of excessive precipitation. For precipitation, the situation is more complicated. Rainfall exhibits notable spatial and temporal variability (Hulme *et al.,* 2005). Inter annual rainfall variability is large over most of Africa and, for some regions; multi-decadal variability is also substantial (IPCC 2007. In West Africa (4°N – 20°N; 20°W – 40°E), a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20 to 40 percent noted between the periods 1931 to 1960 and 1968 to 1990 (Nicholson *et al.,* 2000; Chappell and Agnew, 2004; Dai *et al.,* 2004). In the tropical rain-forest zone, declines in mean annual precipitation of around 4 percent in West Africa, 3 percent in North Congo and 2 percent in south Congo for the period 1960 to 1998 have been noted (e.g. Malhi & Wright, 2004). A 10 percent increase in annual rainfall along the Guinean coast during the past 30 years has, however, also been observed (Nicholson *et al.,* 2000). In other regions, such as southern Africa, no long-term trend has been noted. Increased inter annual variability has, however, been observed in the post-1970 period, with higher rainfall anomalies and more intense and widespread droughts reported (e.g., Richard *et al.,* 2001; Fauchereau *et al.,* 2003). However, climate change is evident when excessive rainfall or overflow of water submerge a dry land in the form of floods. Floods are also critical and have a severe impact on agriculture and development in Africa. In some cases, recurrent floods in some countries are linked with ENSO events. When such events occur, important economic and human losses result, for example in Mozambique (Mirza, 2003; Obasi, 2005). Even countries located in dry areas (Algeria, Tunisia, Egypt and Somalia) have not been flood-free (Kabat *et al.,* 2002). Climate change is characterized by a prolonged period of abnormally low precipitation, called drought. Droughts have long contributed to human migration, cultural separation, population dislocation and the collapse of prehistoric and early historic societies (Pandey *et al.,* 2003). One-third of the people in Africa live in drought-prone areas and is vulnerable to the impact of droughts (World Water Forum, 2000). According to Few *et al.* (2004) in Africa, for example, several million people regularly suffer as a result of droughts and floods. The impact of droughts and floods is often further exacerbated by health problems, particularly diarrhoea, cholera and malaria. During the mid-1980s the economic losses from droughts totalled several hundred million US dollars (Tarhule & Lamb, 2003). Droughts have mainly affected the Sahel, the Horn of Africa and southern Africa, particularly since the end of the 1960s (Section 9.6.2; Richard *et al.,* 2001; L'Hôte *et al.,* 2002; Brooks, 2004; Christensen et al*.,* 2007; Trenberth *et al.,* 2007).

2.2.1.3 Climate change based on regional perspective

The warming trend observed in southern Africa over the past few decades is consistent with the global trend of temperature rise in the 1970s, 1980s and particularly in the 1990s. According to the IPCC (2001), temperatures in the region have risen by over 0.5°C over the past 100 years. Between the years1950 and 2000, Namibia experienced warming at a rate of 0.023°C per year (Government of Namibia, 2002). The nearby Indian Ocean has also warmed by more than 1°C since 1950, a period that has also witnessed a downward trend in rainfall (NCAR, 2005). Below normal rainfall years are becoming more and more frequent and the departure of these years from the long-term normal more severe (USAID, 1992). In different parts of southern Africa (e.g. Angola, Namibia, Mozambique, Malawi and Zambia), a significant increase in heavy rainfall events has also been observed (Usman & Reason, 2004), including evidence changes in seasonality and weather extremes (Tadross *et al.,* 2005a; New *et al.,* 2006).

2.2.1.4 Climate change based on national and provincial perspective

South Africa, like other countries mentioned in this literature review, is equally confronted by adverse impacts of climate change. In South Africa, the minimum temperatures have increased slightly faster than maximum or mean temperatures (Conway *et al.,* 2004; Kruger & Shongwe, 2004). Between the years 1961 and 2000, there was an increase in the number of warm spells over southern and western Africa, and a decrease in the number of extremely cold days (New *et al.,* 2006). In South Africa, between 1960 and 2003, the mean temperature increased by 0.13°C (Kruger & Shongwe, 2004), and mean rainfall is expected to decrease by 5-10 percent within the next 50 years (Hewitson 1999; Durand 2006). The expected reduction in rainfall will have a significant impact on South Africa's agriculture because a large portion of the country is semi-arid and experiences varying and low mean rainfall of 464 millimetres annually, relative to the world average of 857 millimetres (BFAP, 2007).

Climate change is a threat to agricultural production in South Africa. According to Mandleni (2011) climate change has been found to have serious environmental, economic and social impacts in South Africa. Climate change involving a decline in rainfall poses a threat to agricultural productivity which depends on sufficient rain. Mandleni (2011) further states that most rural farmers depend on natural resources, agriculture and especially livestock production for their livelihoods. Gbetibouo (2006) report was that rainfall was characterized by large inter-annual variability, with the previous three years being very dry. In general, South Africa is a water scarce country and has also developed most of its water resources (Benhin, 2006). It is expected to be among the worst water scarce countries by 2025. In the northern parts of the country, both surface and groundwater resources are nearly fully developed and used. The reverse applies to the well-watered south-eastern region of the country where there are still significant underdeveloped and little used resources (Sally & Kamire, 2002). Water is indeed the factor that most limits agricultural development in the country, with more than 50 percent of South Africa's water already used for agricultural purposes (Benhin, 2006). There is evidence that climate change could cause increased variability of climate over the eastern parts of South Africa (mainly sub-tropical wet zone), and a further decrease in rainfall from the west (desert and arid zones) and over the Western Cape region (winter rain zone) (DWAF, 2002).

2.2.2 The climate system

In order to understand climate change an understanding of climate system is important and it is discussed extensively in this section. According to Exploratorium (2002) the key to understanding global climate change is to firstly understand what global climate is, and how it operates. The global climate system is a consequence of, and a link between, the atmosphere, oceans, the ice sheets (cryosphere), living organisms (biosphere) and the soils, sediments and rocks (geosphere). The definition for the climate system makes it clear that one has to have an understanding of all of that system's components (atmosphere, ocean, land surface processes, cryosphere, and biosphere) in order to understand it. This primer is organized into four interconnected sections: the atmosphere; the hydrosphere (the earth's oceans and water); the cryosphere (the areas of the planet covered by snow and ice); and the biosphere (the living organisms inhabiting all these domains) (Houghton, 2002). Climate change and the need for environmental protection are global problems and call for a knowledgeable response from all countries in order to be effectively addressed.

The term climate change is used with different meanings and perspectives. In some cases it may refer to all environmental change or include natural variability. It is most useful to think of climate change as one of several symptoms of human-induced environmental change with both global and local perspectives. A global perspective is appropriate to recognise the global interactions involving the component physical systems fundamental to climate change. The local perspective is essential because the local impact is of significance to individuals and communities, and because it is at the local level where measurements must be obtained from all parts of the world in order to properly describe climate and predict its changes (WMO, 2002).

2.2.2.1 Atmosphere

The greenhouse effect is essential to our existence: the sun warms the earth, and certain gases (including carbon dioxide and water vapour) act like the glass of a greenhouse, trapping heat and keeping the planet's surface warm enough to support life. However, measuring humanity's effect on the concentration of Greenhouse Gas Emissions (GHGs) is a key issue in understanding global climate change. Industry and other human activity add carbon dioxide to the atmosphere. This strengthens the greenhouse effect and may cause a significant warming trend.

Understanding how the atmosphere works is fundamental to understanding climate change. The atmosphere is composed of layers of air, each with its own temperature patterns. Researchers must determine whether changes in temperature or air circulation are part of complex, long-term cycles. The interconnections between air, sea and land mean that any change could have multiple causes and multiple effects.

2.2.2.2 Hydrosphere

The oceans, which cover more than 70 percent of the earth's surface, play a fundamental and complex role in regulating climate. The oceans absorb huge amounts of solar energy; ocean currents transport this heat from the equator towards the poles. In the past, long-term, natural oscillations in the oceans' capacity to store and transport heat have led to global temperature changes. Future climate changes, whether natural or human-induced, will also be strongly influenced by the powerful dynamics of the oceans.

As part of a vast planetary cycle of evaporation and rainfall, the oceans are also fundamental to the movement of water around the globe. Measuring changes in precipitation patterns, and understanding how they may lead to droughts in some regions and flooding in others, is a major part of predicting the potential effects of global climate change on human activities and natural ecosystems.

2.2.2.3 Cryosphere

Changes in climate dramatically alter the planet's snow and ice covered cryosphere. With variations in the earth's temperature, thousands of square miles of snow and ice can accumulate or melt. Changes in snow and ice cover, in turn, affect air temperature, sea level, ocean currents, and storm patterns. Snow and ice help keep the earth cool by reflecting between 60 percent and 90 percent of the solar energy that shines on them back into space (Exploratorium, 2002). Reduction of snow cover and sea ice may lead to increased warming, as more solar energy is absorbed.

Climate models suggest that global warming will be felt most acutely in the polar regions, particularly the Arctic regions. Researchers have already observed many changes in the Arctic, including the warmest temperatures in the past 400 years, an earlier melting of ice on lakes and rivers, and a decline in the extent of spring and summer sea ice. Studying the cryosphere also gives scientists valuable insights into how and why the earth's climate has changed in the past, how it is currently changing, and what may lie ahead. Ice at the poles and in glaciers contains detailed records of past climate conditions, including bubbles that capture samples of the earth's ancient atmosphere. By examining ice cores cylinders of ice taken from deep below the surface scientists gather data dating back hundreds of thousands of years.

2.2.2.4 Biosphere

The effects of climate change on plants and animals are difficult to measure, but potentially dramatic. Many species inhabit precisely bounded ecological niches, and even small changes in climate may cause fundamental disruptions in habitat or food availability. In the past, animals could respond to these pressures by moving from one place to another. Today, however, land development has constrained and fragmented ranges and travel routes, making species migration in response to climate change much more difficult. Moreover, loss of key predator or prey species may affect the life cycles of other organisms in the food chain.

Organic processes can also play an important role in regulating the earth's climate. Changes in the extent of snow, ice or vegetation covering the planet's surface can alter key climatic processes with unforeseeable effects (changing the amount of carbon dioxide consumed by plants, for example, or the proportion of the sun's heat absorbed by the earth).

Biological evidence can also help researchers understand other processes. Sometimes, people keep records that offer clues to climate patterns such as the changing dates of bird migrations, or the onset of spring. Other records that come from nature such as tree rings, preserved bones and fish scales in ocean sediments go back farther than more direct measures of climate, making them valuable indicators of climate change.

Over the past few decades, evidence of human influences on climate change has become increasingly clear and compelling (Suzuki, 2010). There is indisputable evidence that human activities such as electricity production and transportation are adding to the concentrations of GHGs that are already naturally present in the atmosphere. These heat-trapping gases are now at record-high levels in the atmosphere compared to the recent and distant past. Warming of the climate system is well-documented, evident from increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels. The build-up of GHGs in the atmosphere is very likely the cause of most of the recent observed increase in average temperatures, and contributes to climate change.

2.3 Causes of climate change

Climate change might result from natural factors and processes or from human activities. The term "climate change" is often used interchangeably with the term global warming but different from each other**.** Global warming refers to an average increase in the temperature of the atmosphere near the earth's surface, which can contribute to changes in global climate patterns (EPA, 2004). It is one of the most controversial scientific issues of the 21st century. According to Spore (2008) each day, the sun emits rays of light onto the earth's surface. The earth absorbs part of the heat, reflects another share into the atmosphere and sends out a third share in the form of infra-red rays. The problem we are facing today is that there is a concentration of GHGs produced by human activity which increased significantly over time. The gases absorb the terrestrial radiations from the earth and re-radiate the heat back to earth, thereby leading to a general increase in temperature known as global warming.

The earth's climate system is driven by heat energy from the sun. Several gases in the atmosphere act to trap the energy from the sun, thus warming the earth. These gases are called greenhouse gases (GHGs) and the process is the greenhouse effect. Without this process there would be no life on earth. Human activities over the past 200 years, particularly the burning of fossil fuels (oil, coal, natural gas) and the clearing of forests, have increased the concentration of GHGs in the atmosphere (IPCC, 2010). This means more heat is being trapped, which leads to the earth's surface warming up – called the enhanced greenhouse effect.

Climate change, as a result of human activities, has the potential to affect all natural systems thereby becoming a threat to human socially, politically and economically. Anthropogenic activities such as the burning of coal, oil, and natural gas, as well as deforestation and various agricultural and industrial practices, are altering the composition of the atmosphere and contributing to climate change. These human activities have led to increased atmospheric concentrations of GHGs. Since 1988 when the IPCC started, four assessments have been conducted to date. These assessments show that warming of the climate system is unequivocal. The IPCC Fourth Assessment Report (2007) stated that continued GHG emissions would induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century (Pachauri, 2009).

2.3.1 Climate change causes based on international perspective

Scientific evidence gathered by the IPCC (2007) confirms that global warming is occurring and that the increase in global temperature is a result of human activities. These activities, principally the large-scale usage of fossil fuels, including coal, oil and gas, result in increasing emissions of GHGs into the atmosphere, including carbon dioxide (CO_2) methane and fluorocarbons (ACTSA, 2009). Coal remains the primary source of fuel for power plants and most countries are heavily dependent on fossil fuels for their energy needs. The transport sector is responsible for high carbon emissions, especially car travel, road freight, shipping and air transport, since almost all of the energy consumed is oil based. Rich industrialized countries have historically produced most of the carbon emissions and are still the principal polluters, albeit with emerging economies catching up in the past decade (ACTSA, 2009). For instance, in 2006 China became the biggest contributor to GHG emissions globally. Today, the Group of 20 (G20) countries, those with the largest global economies, are responsible for approximately 80 percent of the world's GHG emissions (ACTSA, 2009).

In addition, Maponya and Mpandeli (2012) indicate that the nature of the climate change impact will be affected by the agriculture sector's own growth since its emissions also contribute to climate change. As agreed by the majority of scientists, climate change is mainly driven by the emission of GHGs, such as carbon dioxide, methane and nitrous oxide (IPCC, 2007). Among other sources of emissions, agriculture is one of the most important contributors. According to Smith (2008) energy and chemical-intensive farming has led to increased levels of GHG emissions, primarily as a result of the overuse of fertilizers, land clearance, soil degradation, and intensive animal farming. The total global contribution of agriculture to climate change, including deforestation to create farmland and other land use changes, is estimated to be equivalent to between 8.5 to16.5 billion tonnes of carbon dioxide or between 17 to 32 percent of all human-induced GHG emissions (Smith, 2008).

Many elements contribute to climate change. According to the IPCC (2007), agricultural livestock account directly for about 9 percent of the total anthropogenic GHG emission, on a global scale. Livestock production and associated activities, which includes the livestock production lifecycle, burning of fossil fuel to produce mineral fertilizer used in feed production, methane release from the breakdown of the fertilizer and from animal manure, land-use changes for feed production and for grazing, and degradation, fossil fuel use during feed and animal production, fossil fuel use in production and transport of processed and refrigerated animal products are estimated to be about 18 percent of global anthropogenic emission (Gill *et al.,* 2010). Gill also estimate that methane emissions accounting for 30 percent of these emissions, similar to the relative contribution of N20, while land use and land-use change, together with deforestation related to provision of grazing, account for 38 percent. These are mostly experienced in countries in Europe.

In Latin America, FAO (2010) reported that grazing occupied 26 percent of the earth's terrestrial surface which was due to the expansion of grazing land through deforestation. Deforestation resulted in overgrazing, soil compaction and erosion attributable to livestock activity. According to Clark *et al.* (2011) in New Zealand, enteric methane (CH4) emissions arising from the ruminant animals constitute 30 percent of total CO_2 emissions. Enteric methane gas (ch4) emissions have increased by 9 percent since 1990. Hope *et al.* (2001) discovered that ruminants contributed a significant amount of methane and nitrous oxide due to manure management and fertilizer application to the total GHG emissions in the United State of America.

2.3.2 Climate change causes based on continental perspective

The cause of the warming of the African continent (and of the world as a whole) over the past 100 years is not entirely clear. The change in atmospheric composition associated with rising levels of GHGs must be one of the most plausible explanations, but there are other possibilities (Wigley *et al.,* 1992). The trend may, for example, be the result of natural climate variability, shifts in the ocean temperature distribution or changes in the solar output. The progressive degradation of dry land areas, by reducing surface soil moisture, may have contributed to the warming over Africa, although the results of recent analyses suggest that the effects may account for no more than a small proportion of the trend observed over the continent as a whole (cf. Balling, 1991, with Hulme & Kelly, 1993).

The findings of the IPCC (2007) clearly stated the observations and events in the Niger delta region of Nigeria where it is estimated that over 70 million cubic meters daily, amounting to about 70 million tonnes of carbon dioxide are flared off during oil and gas exploration and production activities (UNDP/World Bank 2004). Approximately 75 percent of total gas production in Nigeria is flared. It has been estimated that Nigeria accounts for about 17.2 percent of global gas flaring. As a result, more gas is flared in Nigeria's Niger delta than anywhere else in the world (EIA, 2003).

Thaddeus *et al.* (2011) however reported that human activities have tended to exacerbate climate change and its impact on agriculture and livelihoods in some communities in Nigeria. An example is the Niger delta region of Nigeria which is reported to have over 123 gas flaring sites making Nigeria one of the highest emitters of GHGs in Africa (Akinro *et al.,* 2008). A recent study by the World Bank (2008) revealed that Nigeria accounts for roughly one-sixth of worldwide gas flaring. Nigeria flares about 75 percent of its gas and all take place in the Niger delta region. At the same time, the low-lying Niger delta is particularly vulnerable to the potential effects of sea levels rising (Ugochukwu, 2008; Ugochukwu *et al.,* 2008).

Climate change in the Niger delta affects rainfall patterns, emergence of diseases and pests, crop and animal production, fisheries, biodiversity, frequency and regularity of floods, human health. It has been suggested that climate change could potentially contribute to increased incidences of flooding. This has been the case for many communities in the Niger delta region which as a result puts lives at risk with serious consequences for property, livelihoods and the environment. The flares have apparently contributed more GHGs to the surrounding areas. In other words, burning of flares is a human activity causing climate change.

Creating hydropower energy could also be the cause of climate change. According to Josephine *et al.* (2012) hydropower is a major source of energy within the East Africa region. Hydropower is, however, highly vulnerable to fluctuations in rainfall in the sense that too little rainfall leads to droughts while too much leads to floods. The consequence of drought is climate change which affects agriculture. Low water levels in the dams to generate electrical power lead to huge economic losses and negative economic development of a nation because power usage have to be rationed in the industries. This leads to a redundancy of factory employees whose operations are dependent on electricity. On the other hand, too much rainfall often leads to floods that could cause dam breakages and siltation (ICPAC, 2006).

2.3.3 Climate change causes based on regional perspectives

The least developed countries, including most of those in southern Africa, are minor contributors to climate change. South Africa, a member of the G20, is the largest carbon emitter on the African continent and in 2007 it was the 13th highest emitter globally. The country, however, is still far behind the likes of the USA, China and the UK (ACTSA, 2009). According to ACTSA (2009) the South African government has recently committed to limiting its emissions significantly by implementing energy efficiency measures and investing in carbon-friendly technologies. The country currently relies on coal to produce most (90%) of its energy.

Another cause of climate change is deforestation. Trees and plants including wood and leaves absorb CO_2 from the atmosphere and turn it into biomass. Therefore, deforestation can lead to further global warming by contributing to significant levels of emissions in the atmosphere. According to estimates by the IPCC (2001) deforestation produces 5.9 billion tonnes of CO_2 per year and 18 percent of global CO_2. Furthermore, deforestation illustrates the ongoing reliance of many African countries on primary extraction rather than sustainable industrial and manufacturing activities. In addition, several other human activities have led to increased atmospheric concentration of a number of GHGs, including changes in land use pattern, land clearing and agriculture.

2.4 Maize production in South Africa

Maize is a cereal crop grown widely throughout the world in a range of agro-ecological environments. More maize is produced annually than any other grain (IITA, 2009). About 50 species exist and consist of different colours, textures and grain shapes and sizes. White maize, yellow maize and red maize varieties are the most common types (FAO, 2009). The white and yellow varieties are preferred by most people depending on the region. Worldwide production of maize is 785 million tonnes, with the largest producer, being the United States, producing 42 percent. Africa produces 6.5 percent and the largest African producer is Nigeria with nearly 8 million tonnes, followed by South Africa. Africa imports 28 percent of the required maize from countries outside the continent. Most maize production in Africa is rain fed. Irregular rainfall can trigger famines during occasional droughts. According to the IITA (2009) maize was introduced into Africa in the 1500s and has since become one of Africa's dominant food crops. Like many other regions, it is consumed as a vegetable although it is a grain crop. The grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9 percent protein. They are also rich in dietary fibre and calories which are a good source of energy.

Climate change could have a significant impact on South African maize production (Akpalu *et al.,* 2008) According to IFPRI (2008) maize is the primary food staple in southern Africa, and 50 percent of the total maize output in the area is produced in South Africa, where maize constitutes approximately 70 percent of grain production and covers 60 percent of the country's cropping area. According to a fact established by the scientific community temperature in South Africa increased significantly between 1960 and 2003 (by 0.13°C), and changes in the quantity and pattern of rainfall are expected despite attempts by the international community to reduce GHG emissions. This significant climate change will obviously also has an impact on maize production.

Maize production is influenced by several factors. Ambient temperature, precipitation and soil moisture as well as frequency of heat, waves and droughts are significant factors influencing corn production in southern Africa. It is a summer crop, mostly grown in semi-arid regions of the country, and is highly susceptible to changes in precipitation and temperature (Durand 2006; Benhin 2006). Although the maize plant is quite hardy and adaptable to harsh conditions, a drier or warmer climate and lower precipitation could have detrimental effects on its yield (BFAP, 2007). A considerable number of studies have been done to investigate the impact of climate change on yields of grain crops such as maize under controlled experiments (Du Toit *et al.,* 2002; Kiker *et al.,* 2002; Durand, 2006).

2.4.1 Maize production and climate variability

Research indicates that climate variability acts negatively on agriculture production. According to Akpalu *et al.* (2008) farming, which is mainly supported by rain in Africa, provides employment to over 70 percent of the labour force. Fleshman (2007) states that about a third of the population lives in drought-prone regions. This shows how helpful farming could be to Africa. Farming is, however, being challenged by unprecedented climate change. According to the IPCC (2007), there is a statistically significant increase in the global mean state of the climate or in its variability, and further increases are expected if carbon dioxide and GHG emissions are not controlled. According to Kruger and Shongwe (2004) in South Africa, between 1960 and 2003, the mean temperature increased by 0.13°C and mean rainfall is expected to decrease by 5 to10 percent within the next 50 years. The expected reduction in rainfall will have a significant impact on South Africa's agriculture because a large portion of the country is semi-arid and experiences varying and low mean rainfall of 464 millimetres annually, relative to the world average of 857 millimetres (BFAP, 2007).

The impact of climate change shows a drastic negative impact on the yield of maize. Findings on the impact of climate change and crops in South Africa by Akpalu *et al.* (2008) indicated a result that suggests that a change in the amount of precipitation is the most important driver of maize yields. A 10 percent reduction in mean precipitation reduces the mean maize yield by approximately 4 percent. An increase in mean precipitation increases the mean maize yields. However, as rainfall continues to increase, the additional gain in maize yield begins to diminish. As the mean temperatures increase from 21.4 to 21.6°C the average maize yield increases by 0.4 percent. However, like increased precipitation, the gain in maize yields prompted by increased temperature begins to diminish as temperature increases further. This shows that at a particular temperature and rainfall, there is an optimum yield of maize, above and below reduces the yield.

2.5 Impact of climate change

The greatest challenge that confronts human beings and societies today and the generations to come is the issue of climate change. Our societies are dominated and even driven by ideas and products from science and technology (Igwe, 2003). And it is very likely that its influence on our lives will continue to increase in the future. Various global problems facing us today emanated from global scientific collaborations that depend largely on the ecosphere (Sjoberg, 2002). The effects resulted in the experience of the terrible environmental problem enumerated by Udenyi (2010) such as global warming, ozone layer depletion, acid rains, extinction of wild life, extinction of various tropical plants, earthquakes/volcanic eruptions, floods disaster, rock fall, mud flow, hurricanes/hail storms, melting of ice sheet in the poles region, droughts, desertification, heat wave, windstorms, forest fires in California.

The impacts of global climate change on agricultural production may be significant (Rosenzweig & Parry 1994). Despite technological advances in plant breeding, fertilizers and irrigation systems, improved varieties, genetically modified organisms, and irrigation systems, climate is a key factor in agricultural production. In the 1980s, continuing deterioration of food production in Africa was caused in part by extended drought and soil degradation. Assessments of climate change impacts on crop production in developed countries have been completed (Smith & Tirpak, 1989) but less is known about the impact in developing countries. According to Hughton (2002) the earth's average surface temperature has increased by 1°F just over the past century.

Climate change aggravates the negative impact on crop yield. A study published by BFAP (2007) suggests that, due to climate change, southern Africa could lose more than 30 percent of its main crop, maize, in the near future. In South Asia, losses of many regional staples, such as rice, millet and maize could top 10 percent. The IPCC Third Assessment Report (2001) concluded that the poorest countries would have more negative impact, with reductions in crop yields in most tropical and sub-tropical regions due to a decrease in water availability, and new or changed insect pest incidence. Also according to the publication, in Africa and Latin America, many rain-fed crops are near their maximum temperature tolerance, so that yields are likely to fall sharply, even if the changes in climate are small. A decline in agricultural productivity of up to 30 percent over the 21st century is projected. Changes in climate induced by increasing GHGs are likely to affect crops differently from region to region. For example, according to the IPCC (2007) average crop yield is expected to drop down to 50 percent in Pakistan whereas corn production in Europe is expected to grow up to 25 percent in optimum hydrologic conditions. In a nut shell, climate change variability affects crop yield.

Research on the effects of climate change by the Australian parliament (2008) indicated that there was growing evidence that climate change, particularly rising temperatures, was already having a significant impact on the world's physical, biological and human systems, and it was expected that these impacts would become more severe. Warmer temperatures are causing changes in the hydrological cycle at regional and global scales, including decreases in the amount of water stored as ice in most of the world's glaciers, ice sheets and sea ice; decreasing snow cover and earlier snow melt; and changes in rainfall patterns. These changes affect the incidence and severity of drought and floods and the availability of water, which in turn present challenges to many aspects of human society and industry (e.g. agriculture, rural economies, insurance, water security and food security). Sea level rise due to losses from ice stores and thermal expansion is another consequence of climate change that will have an increasing impact on human settlements and infrastructure.

Climate change threatens humans' basic needs. According to the National Research Council (NRC, 2010) many global issues are climate related, including basic needs such as food, water, health and shelter. Changes in climate may threaten these needs with increased temperatures, sea level rise, changes in precipitation, and more frequent or intense extreme events. Climate change will affect individuals and groups differently. Certain groups of people are particularly sensitive to climate change impacts, such as the elderly, the infirm, children, native and tribal groups, and low-income populations. Although climate change is an inherently global issue, the impacts will not be felt equally across the planet. Impacts are likely to differ in both magnitude and rate of change in different continents, countries, and regions. Some nations will likely experience more adverse effects than others (EPA, 2004). Other nations may benefit from climate change. The capacity to adapt to climate change can influence how climate change affects individuals, communities, countries, and the global population.

2.5.1 Impact of climate change across the globe

2.5.1.1 Impacts in Africa

The impact of climate change in Africa is real. According to Boko *et al.* (2007) Africa is one of the most vulnerable continents to climate variability and change because of multiple existing stresses and low adaptive capacity. Climate variability and change is projected to severely compromise agricultural production, including access to food, in many African countries and regions. Towards the end of the 21st century, projected sea level rise will likely affect low-lying coastal areas with large populations. The impact of climate change on agriculture may add significantly to the development challenges of ensuring food security and reducing poverty.

Maize production is found to be highly affected by climate variability and change. There is a negative impact on the yield of maize when there is a decrease in mean precipitation simultaneous with a marginal increase in mean temperature or vice versa (Akpalu *et al.,* 2008). A study of the influence of climate variability on crop yield by Chi-Chung *et al.* (2004) revealed that precipitation and temperature were found to have opposite effects on yield levels and variability of corn (maize). Furthermore, more rainfall could cause yield levels to rise, while decreasing yield variance and temperature changes could have a reverse effect on maize production. Studies have indicated that 1°C increase in global temperature will lead to reduced productivity in some cultivated plants, such as maize and soybean (Allen *et al.,* 2003 &Thomson *et al.,* 2005). Drought also negatively affects all stages of maize growth and production, the reproductive stage particularly between tassel emergence and early grain filling is the most sensitive to drought (Grant *et al.,* 1989). This occurs mostly in the northern regions of Africa where there is an absence or shortage of precipitation.

2.5.1.2 Impacts in Asia

In Asia, climate change could have an impact on the sea level. According to Cruz *et al.* (2007) glaciers in Asia are melting at a faster rate than ever documented in historical records. Melting glaciers increase the risks of flooding and rock avalanches from destabilized slopes. Climate change is projected to decrease freshwater availability in central, south, east and south-east Asia, particularly in large river basins. With population growth and an increasing demand emanating from higher standards of living, this decrease could adversely affect more than a billion people by the 2050s. Cruz *et al.* (2007) further state that increased flooding from the sea and, in some cases, from rivers, threaten coastal areas, especially heavily populated delta regions in south, east, and south-east Asia. By the mid-21st century, crop yields could increase up to 20 percent in east and south-east Asia. In the same period, yields could decrease up to 30 percent in central and southern Asia. Sickness and death due to stomach disease are projected to increase in east, south and south-east Asia because of projected changes in the hydrological cycle associated with climate change.

Asia is the leading cereal producer in the world. Particularly two crops place Asia in the leading position, namely rice and wheat. Asia produces 90 percent of the world’s rice and 40 percent of the world’s wheat. Rice is the major food staple grown in Asia. Asia is the second largest producer of coarse grains, after northern America, with 24 percent of the world’s production (FAO, 2009a). Climate change is already impacting rice production. The yield of rice was observed to decrease by 10 percent for every 1°C increase (IPCC, 2007b). Also, there would be a negative impact on central and southern Asia, with crop yields decreasing up to 30 percent. However, there is a positive impact in east and south-east Asia, with crop yields increasing up to 20 percent (IPCC, 2007b). China, as an example in east Asia, produce 20 percent (166 million tonnes) of the maize in the world, is positioned as the second largest producer; and the fourth producer of soybeans, with 6.7 percent (15.5 million tonnes) of the total production (FAOSTAT, 2009d).

2.5.1.3 Impacts in Australia and New Zealand

Australia and New Zealand experience water stress. According to Hennessy *et al.* (2007) water security problems are projected to intensify by 2030 in southern and eastern Australia, and in the northern and some eastern parts of New Zealand. Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics. The rise in sea level and more severe storms and coastal flooding will likely impact coastal areas. Coastal development and population growth in areas such as Cairns and south-east Queensland (Australia) and Northland to Bay of Plenty (New Zealand), could place more people and infrastructure at risk (EPA, 2004). By 2030, increased drought and fire are projected to cause declines in agricultural and forestry production over much of southern and eastern Australia and parts of eastern New Zealand. Extreme storms are likely to increase failure of flood plain protection and urban drainage and sewerage, as well as damage from storms and fires. More heat waves may cause more deaths and more electrical blackouts.

Wheat is the largest crop in Australia, ranking as the ninth biggest wheat producer in the world, with 3 percent (21.4 million tonnes) of the world's total production (FAOSTAT 2009d). The south-western Australian regions are likely to have a significant reduction in wheat production, while the north-eastern regions of Australia are likely to have moderate increases in yield (IPCC 2007b). Madiyazhagan *et al.* (2004) carried out a study on water and high temperature stress effects on maize production in Australia. They observed that high temperatures (above 38ºC) compounded by water stress occurring at the same time decreased kernel set in dry land environments.

2.5.1.4 Impacts in Europe

Wide ranging impacts of climate change have already been documented in Europe. According to Alcamo *et al.* (2007) these impacts include retreating glaciers, longer growing seasons, species range shifts, and heat wave-related health issues. The future impact of climate change is projected to negatively affect nearly all European regions. Many economic sectors, such as agriculture and energy, could face challenges (EPA, 2004). In southern Europe, higher temperatures and drought may reduce water availability, hydropower potential, summer tourism and crop productivity. In eastern and central Europe, summer precipitation is projected to decrease, causing higher water stress. Forest productivity is projected to decline. The frequency of peat land fires is expected to increase. In northern Europe, climate change is initially projected to have both a positive and negative impact which includes some benefits such as reduced demand for heating, increased crop yields, and increased forest growth. However, as climate change continues, negative impacts are likely to outweigh these benefits. The negative results include more frequent winter floods, endangered ecosystems, and increasing ground instability (Alcamo *et al.,* 2007).

Most of European countries fall within the mid-latitude region with a temperate climate. Except few countries with a high-latitude of polar climate which includes Finland, Norway, Sweden and the northern part of the Russian Federation. However, this means that about 84 percent of the arable land in Europe would be affected by climate change with changes in precipitation (IPCC, 2007b). An increase in crop yields is expected mainly in northern Europe (e.g. Norway, Finland and Sweden) for example, wheat increases of 5 percent on average by 2020; while the largest reductions of all crops are expected in the Mediterranean (Italy, Spain and France), with estimates of up to 10 percent decrease.

2.5.1.5 Impacts in Latin America

Water availability is one of the major challenges in some countries in Latin America. Cruz *et al.* (2007) indicate that by mid-century increases in temperature and decreases in soil moisture are projected to cause savannah to gradually replace tropical forest in eastern Amazonia. In drier areas, climate change will likely worsen drought, leading to salinization (increased salt content) and desertification (land degradation) of agricultural land. The productivity of livestock and some important crops such as maize and coffee is projected to decrease, with adverse consequences for food security. In temperate zones, soybean yields are projected to increase. Sea level rise is projected to increase risk of flooding, displacement of people, salinization of drinking water resources, and coastal erosion in low-lying areas. Changes in precipitation patterns and the melting of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation.

Most of the Latin American countries and the Caribbean region fall within low latitude, meaning that 82 percent of the arable land in Latin America would be affected by climate change due to reduced water availability, and changes in precipitation in dry areas (IPCC, 2007b). According to (FAOSTAT, 2009d) about 13 percent (105 million tonnes) of the world's production of maize is currently produced in Brazil, Mexico and Argentina. Brazil is estimated to experience 15 percent yield reduction in maize while Argentina will also experience reductions in yields from maize by up to 5 percent (IPCC, 2007b).

2.5.2 Impact of climate change on agriculture and food

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

In Asia, more frequent and extreme events, such as droughts and floods, are expected to make local crop production even more difficult. It is projected that climate change will put around 49 million more people at risk of hunger by 2020 (IFAD, 2009). In particular, it is expected that crop yields could increase up to 20 percent in east and south-east Asia while they could diminish up to 30 percent in central and southern Asia by the mid-21st century. Moreover, northeast China, flood-prone river deltas of Bangladesh and Vietnam are currently facing a water crisis. These areas are expected to experience significant land degradation and loss in a changing climate. Considering the pressure of fast population growth and urbanization, the risk of hunger is expected to remain extremely high in several developing countries. Furthermore, for the least developed nations, such agriculture impacts may threaten not only food security, but also national economic productivity. According to Hall (2009) climate change impacts will be overwhelmingly severe in Asia. Asia's rapidly growing population is already home to more than half of humanity and a large portion of the world's poorest people.

Fisheries, as a branch of agriculture, are also being affected by climate change. Increasing ocean temperatures have shifted some marine species to cooler waters outside of their normal range. Fisheries are important for the food supply and economy of many countries. For example, more than 40 million people rely on the fisheries in the lower Mekong delta in Asia. Projected reductions in water flows and increases in sea levels may negatively affect water quality and fish species in this region (EPA, 2004). This would affect the food supply for communities that depend on these resources.

2.5.2.2 Climate change impacts on agriculture and food based on continental perspective

Changes in climate could have a significant impact on food production all over the continent of Africa. Heat stress, droughts and flooding events may lead to reductions in crop yields and livestock productivity. According to FAO (2009) countries in Africa will be the hardest hit in terms of future food security. By 2080, climate change would render Africa and certain parts of Asia the most food insecure, with 75 percent of the world’s hungry desperate for food (Schulze, 2005).

Livestock production is also vulnerable to climate variability and change. According to Maponya and Mpandeli (2012) the impact climate change in Africa will bring about is expected to exacerbate the vulnerability of livestock systems and to reinforce existing actors that are simultaneously affecting livestock production systems such as rapid population and economic growth, increased demand for food (including livestock) and products, increased conflict over scarce resources (i.e. land tenure, water, bio fuels). This is supported by this fact that there is every reason to expect that African livestock will be sensitive to climate change (IPCC, 2007). This also buttresses Delgado *et al.* (1999) that livestock systems in Africa are changing rapidly in response to a variety of drivers.

Climate variability has a negative impact on crop yield in Africa. According to IFPRI (2009) the negative impact of climate change on crop yield is pronounced in Africa, as the agriculture sector accounts for a large share of gross domestic product, export earnings and employment. Lobell (2010) emphasised that Africa could face a 30 percent decline in maize production in the next two decades because rainfall and temperature in Africa are changing quite fast. In a study on crop yield variability as influenced by climate, Chi-Chung *et al.* (2004) submitted that precipitation and temperature are found to have opposite effects on yield levels and variability of corn (maize). Furthermore, they reasoned that more rainfall could cause yield levels to rise, while decreasing yield variance and that temperature has a reverse effect on maize production.

2.5.2.3 Climate change impacts on agriculture and food based on regional perspective

In the developing countries, such as South Africa, livestock is considered to be the backbone of agriculture as it provides draught power and farmyard manure before the promotion of modern agriculture in the middle of the 20th century (Mandleni, 2011). According to Thornton *et al.* (2006) livestock production in southern Africa is prone to climate change impacts. The impact of climate change on livestock is likely to be felt from an increased severity and frequency of drought. Deterioration of pastures during droughts, and periods of over-grazing can result in poor health and death of livestock, which have an impact on food and livelihood security of those who own livestock. Maponya and Mpandeli (2012) outlined that the impact of climate change will have a negative impact in Botswana, South Africa and Namibia which are involved in large-scale livestock production.

The production of maize is affected by drought in the region. Maize, which happens to be the main staple food in southern Africa, fell short by 2.18 million metric tonnes due to droughts in Namibia, Mozambique, Swaziland, Zimbabwe and South Africa (Musvoto, 2009). In addition, maize production in the country constitutes about 50 percent of the output within the Southern African Development Community (SADC) region (Durand, 2006). According to Musvoto (2009) it was emphasized that flooding in the Zambezi basin has been affecting Angola, Botswana, Namibia, Zambia and Zimbabwe. Both the Seychelles and Zambia have been experiencing a mixture of increased droughts and increased flooding which had a great impact on the yield of maize crop.

2.5.2.4 Climate change impacts on agriculture and food based on national and provincial perspective

Maize constitutes about 70 percent of grain production and covers about 60 percent of the cropping area in South Africa. It is a summer crop, mostly grown in semi-arid regions of the country, and is highly susceptible to changes in precipitation and temperature (Durand, 2006; Benhin, 2006). According to StatsSA (2007) maize production contributed 71 percent of grain production in 1996 and to meet the increasing food demand, agriculture has to expand by approximately 3 percent annually. But with the current climate scenario which is becoming hotter and drier, maize production will decrease by approximately 10 to 20 percent over the next 50 years (BFAP, 2007). According to Musvoto (2009) South Africa will have to turn to more drought-resistant strains of maize, or corn, and rely more on the role of genetically modified strains as its western regions dry out. Maize in the Northern Cape province is also predicted to fall from 635000 tonnes from the previous season to 575000 tonnes in 2011 (Modiba, 2011) as a result of climate change and its effects.

2.5.3 Impact of climate change on water resources

2.5.3.1 Water resource based on international perspective

Water quality is important for ecosystems, human health and sanitation, agriculture and other purposes. Increases in temperature, changes in precipitation, sea level rise, and extreme events could diminish water quality in many regions. Salt water from rising sea levels and storm surges threaten water supplies in coastal areas and on small islands. According to IFAD (2009), many areas in the Asia/Pacific region already struggle to manage water resources to ensure a secure supply to growing populations. In particular, maintaining water security is a key priority for the poor rural people of the region, and the impact of climate change on water resources may have a wide array of subsequent negative consequences. Climate change is in fact expected to further modify the availability of water resources, driven by seasonal decreases in rainfall and run-off in south and south-eastern Asia and in run-off in other areas, particularly the Pacific Islands.

Freshwater availability is affected by climate change. According to Harasawa *et al.* (2007) glacier melting in the Himalayas is projected to increase flooding and rock avalanches and to affect water resources within the next two to three decades. This will be followed by decreased river flows as the glaciers recede. Freshwater availability in central, southern, eastern and south-eastern Asia, particularly in large river basins, is projected to decrease due to climate change which, along with population growth and an increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s (IPCC, 2007). Expansion of areas under severe water especially in southern and south-eastern Asia will be one of the most pressing and urgent environmental problems in the region, as the number of poor rural people living under serious water stress is expected to increase substantially in absolute terms.

In Europe, there is an ongoing climatic change that is influencing water resources in a discernible way and even stronger changes are projected for the future (Howells, 2006). The most certain impacts of climate change on freshwater systems are due to increases in temperature, sea level and precipitation variability. According to Wostl and Moltgen

(2006) water management is a good strategy to prepare for climate change. They further emphasize that water management has been successful in the past in securing the availability of water-related services and protecting society from water-related hazards through technical means.

Semi-arid and arid areas (such as the Mediterranean, southern Africa, and north-eastern Brazil) are particularly vulnerable to the impacts of climate change on water supply (EPA, 2004). Over the next century, these areas will likely experience decreases in water resources, especially in areas that are already water-stressed due to droughts, population pressures, and water resource extraction. The availability of water sources is strongly related to the amount and timing of run-off and precipitation. By 2050, annual average river run-off is projected to increase by 10 to 40 percent at high latitudes and in some wet tropical areas, but decrease by 10 to 30 percent in some dry regions at mid-latitudes and in the subtropics. As temperatures rise, snow pack is declining in many regions and glaciers are melting at unprecedented rates, increasing flood risks. Droughts are likely to become more widespread, while increases in heavy precipitation events would produce more flooding (EPA, 2004).

2.5.3.2. Water resource based on continental perspective

Lack of water is a major constraint for development in Africa (Maponya & Mpandeli, 2012). Natural water resources in Africa are being threatened by the impact of climate change and increased water stress. Currently, some 300 million people in Africa suffer from water shortages due to climate variability, increasing water demand, and poor management of existing resources (IPCC, 2007). Nyong and Kandil (2009) indicate that water is a key component of Africa’s natural resources endowments and is fundamental to economic development. They further state that Africa is exceptional disadvantaged with regard to water resources and there is a growing demand from higher population growth, agricultural expansion and industrialization. This matter is worsened by climate change which has made water increasingly scarce in Africa. Even small reductions in rainfall over large areas could cause large declines in river water and it is estimated that by the next decade, between 75 and 250 million people could be exposed to significant water stress due to climate change (Schulze, 2000) There will also be an increased irrigation water demand of 40 to 150 percent for 2020 and 150 to 1200 percent for 2050, a reduction in hydropower generation of 60 percent for 2020 and, by the year 2020, all river basins will be vulnerable and some parts of Africa will face acute water shortage (Schulze, 2000).

2.5.3.3 Water resource based on regional perspective

Water resources in southern Africa are exposed to climate change. According to Schulze *et al.* (2005) southern Africa's water is largely driven by climate and rainfall and river flows display high levels of variability with important consequences for the management of water resource systems. Nyong and Kandil (2009) further emphasise this by saying that a large portion of northern and southern Africa will experience a significant reduction in water availability by mid-century and 250 million people will be exposed to water stress by 2020.

Severe drought affected southern Africa during the early years of the 1990s (Zinyowera & Unganai, 1992). Over parts of southern Zimbabwe and south-eastern Botswana, rainfall was as low as 10 percent of the average value during the rainy season of 1991/92. The drought was largely the result of the El Niño/Southern Oscillation (ENSO) phenomenon, the periodic warming of the tropical Pacific Ocean and related shifts in the atmospheric circulation which brings climatic disruption to many low-latitude areas (Glantz *et al.,* 1991). There is a historic link between the occurrence of ENSO events and drought in southern Africa. The ENSO event of the early 1990s was unusual in that it continued for longer than usual. The drought conditions in southern Africa only eased slightly during the 1992/93 season, although by 1993/94 higher rainfall levels were again being experienced.

During the floods of 2007, the study undertaken by Oxfam (Oxfam GB Cash Transfer Programme) found that 65 percent of the households interviewed were affected by the floods and 33 percent mostly those on the Zambezi plains were displaced and another 17 percent had to relocate to alternative homesteads on the uplands (Bwalya, 2007). According to Schulze *et al.* (2005) water-related problems that already exist in the region are likely to worsen as a result of climate change. Intense rainfall events will increase the incidence of flooding in many areas, however, reduced run-off overall will exacerbate current water stress, reduce the quality and quantity of water available for domestic and industrial use and limit hydropower production.

2.5.3.4 Water resource based on national and provincial perspective

Water in South Africa plays a significant role in agriculture. According to Schulze (2000) South Africa's water sector faces two major challenges, namely limited water resources and the need to ensure that the benefits of those resources are distributed equitably. The adverse impact of climate change will worsen the existing problem of systemic water shortages and will bring forward the limits to water resources. Schulze (2000) further argues that the present population growth trends and water use behaviour indicate that South Africa, as a water scarce country, will exceed the limits of its economically usable, land-based water resources by 2050. According to Schulze *et al.* (2005) South Africa is a dry country with a mean annual rainfall of about 490 mm (half the world average) of which only 9 percent is converted to river run-off. The overall impact of climate change on water resources is uncertain, and will vary significantly from place to place within South Africa.

The impact of climate change on water will be experienced in many places in the country. According to DEA (2010) climate change impacts are not likely to be experienced evenly throughout the country. Some areas will be "winners", other areas will be "losers "while others still, such as the Western Cape and Limpopo provinces, are likely to become real "hotspots of concern". Furthermore, changing rainfall patterns are expected to result in more floods in the eastern part of the country and more droughts in the western parts (DEA, 2010).

2.5.4 Impact of climate change on ecosystem

2.5.4.1 Ecosystem based on international perspective

A network of interactions among organisms, and between organisms and their environment are disrupted by climate variability. According to FAO (2003) Asia has adapted by building resilience of vulnerable human systems, ecosystems and economies to climate change through mobilization of knowledge and technologies to support adaptation capacity building, policy-setting, planning and practices. This in turn gives them access to international finance mechanisms, informs development planning and develops adaptation capacity. According to COAG (2007) Australia is expected to have damaged coral reefs, coasts, rainforests, wetlands and alpine areas due to climate change. There is also an expected loss of biodiversity including possible extinctions, changed species ranges and interactions, and a loss of ecosystem services.

The tropical vegetation, hydrology and climate system in South America could change very rapidly to another steady state resulting in about 40 percent of the Amazonian forests reacting drastically to this change (Rowell & Moore, 2000). This can results in forests being replaced by ecosystems that have more resistance to multiple stresses caused by temperate increase, fires and droughts. The IPCC (2007) projected climate change in North America will continue to put pressure on natural ecosystems (e.g. rangelands, wetlands, and coastal ecosystems). This projection in climate change should be seen as an additional factor that can influence ecosystems.

2.5.4.2 Ecosystem based on continental perspective

Ecosystem in Africa has led to the extinction of some animals as a result of climate variability and change. According to Maponya and Mpandeli (2012) climate change is an added stress to already threatened habitats, ecosystems and species in Africa, and is likely to trigger species migration and lead to habitat reduction. *Boko et al.* (2007) acknowledged that in Africa many ecosystems will be overcome by an unprecedented combination of climate change and linked events, such as flooding, drought, wildfire, insects, ocean acidification and overexploitation of resources.

2.5.4.3 Ecosystem based on regional perspective

Ecosystem is an important resource for southern African communities (IPCC, 2001. However, the ecosystem is being disrupted by the unprecedented change in climate which subsequently could affect livestock. According to Scholes (2006) climate change is already affecting ecosystems in southern Africa, at a faster rate than anticipated. The IPCC also predicted that there will be major changes in ecosystems with mainly negative consequences for biodiversity and ecosystem services (water and food). Part of the changes is caused by an increase in temperature caused by change in climate. According to Mandleni (2011) increase in temperatures induce heat stress to livestock. A study conducted by Sunil *et al.* (2011) on tropical livestock reveals that increased temperatures affect health and performance together with productive capacity of livestock. Heat stress lower feed intake of animals which in turn reduce their productivity in terms of milk yield, body weight and reproductive performance. Furthermore, heat stress also reduces libido, fertility and embryonic survival in animals. Heat stress resulted in reduced birth weights of calves (Sunil *et al.,* 2011).

2.5.4.4 Ecosystem based on national and provincial perspective

There are many recent researches on plants carried out in South Africa and climate change has always been one of the key factors that affect the production with some dramatic conclusions (McClean *et al.,* 2006; McClean *et al.,* 2005). When global temperatures increase there are huge changes to the world's weather systems with all sorts of knock-on effects.

2.5.5 Impact of climate change on health issues

2.5.5.1 Health issues based on international perspective

Rural populations, older adults, outdoor workers, and those without access to air conditioning are often the most vulnerable to heat-related illness and death. Climate change can influence infectious diseases. The spread of meningococcal (epidemic) meningitis is often linked to climate changes, especially drought. Impacts of climate change on agriculture and other food systems can increase rates of malnutrition (Confalonieri *et al.,* 2007). There are many examples of health impacts related to climate change. Sustained increases in temperatures are linked to more frequent and severe heat stress. The reduction in air quality that often accompanies a heat wave can lead to breathing problems and worsen respiratory diseases.

Many regions have experienced heat-related diseases as a result of unprecedented change in climate. Regions such as Europe, South Asia, Australia and North America have experienced heat-related health impacts (EPA, 2004). According to Martens *et al*. (1999) the principal impacts of climate change on health in Asia will be on epidemics of malaria, dengue, and other vector-borne diseases. In 2000, the global burden of diarrhoea and malnutrition resulting from climate change mostly occurred in south-eastern Asian countries, including Bangladesh, Bhutan, India, Maldives, Myanmar and Nepal (Martens *et al.,* 1999). According to the IPCC (2007) many countries in North America should expect higher temperatures, with heat waves increasing in frequency and intensity. Heat waves will become an increasingly important health risk factor for communities and individuals in North America. According to report of the IPCC (2007) France experienced an increase in temperature of 40°C, leading to over 14,000 deaths.

2.5.5.2 Health issues based on continental perspective

Poor and developing countries lack the capacity to prevent diseases. Certain groups of people in low-income countries such as Africa are especially at risk for adverse health effects from climate change. The risks of climate-sensitive diseases and health impacts can be high in poor countries that have little capacity to prevent and treat illness (EPA, 2004). Some areas of sub-Saharan and west Africa are sensitive to the spread of meningitis, and will be particularly at-risk if droughts become more frequent and severe. Floods are also expected to increase infectious diseases such as cholera, diarrhoea and malnutrition for adults and children (WHO, 2004).The spread of mosquito-borne diseases such as malaria may increase in areas projected to receive more precipitation and flooding. Increase in rainfall and temperature can cause spreading of dengue fever.

Africa is vulnerable to a number of climate sensitive diseases including malaria, tuberculosis and diarrhoea (Guernier *et al.,* 2004).

2.5.5.3 Health issues based on regional perspective

Climate change in southern Africa has critical health implications. Increased flooding could facilitate the breeding of malaria carriers in formerly arid areas (Warsame *et al.,* 1995). High flood frequency and water-logging due to climate change in eco-zones hitherto not associated with malaria will enhance the breeding of mosquitoes and thus the spread of malaria. Malaria will also increase due to the preponderance of stagnant pools of water resulting from flooding related to the rise of the sea-level. New evidence with respect to micro climate change due to land-use changes such as swamp reclamation and deforestation suggest an increase in the occurrence of malaria in new areas (Munga *et al.,* 2006; IPCC, 2007).

2.5.5.4 Health issues based on national and provincial perspective

Water scarcity and its consequences of reduced water quality pose significant threats to human health in South Africa (WHO, 2004). Floods and wind storms are expected to disrupt water-supply, sanitation systems health-care and causing new breeds sites for mosquitoes. According to LIM (2004) South Africa will become generally drier and warmer through climate change and significant impacts are expected to reflect in human health. Climate change could make the provinces of Mpumalanga, Limpopo, North West, KwaZulu-Natal and even Gauteng malaria zones by 2050 if no control measures are implemented (Van Schalkwyk, 2008).

The number of South Africans at high malaria risk may quadruple by 2020 – at an added cost to the country of between 0.1 percent and 0.2 percent of gross domestic product (Van Schalkwyk, 2008).The increasing number of hot days and nights, heat stress is likely to have detrimental effects invulnerable populations, children and the elderly, especially in locations of poor housing infrastructure resulting in lack of labour in the agricultural sector (DEA, 2010). According to Maponya and Mpandeli (2012) climate change will also affect human health indirectly through changes in water quality, air quality and food availability as is already happening in some parts of the Limpopo province. In rural areas climate change will place additional stress on those communities living with AIDS and challenging their livelihoods.

2.6 Future climate change in southern Africa

The future climate change is unpredictable. We are living in a speedily changing environment and we do not have an idea of what is going to happen in the future, ranging from technology to climate variability and change. There is widespread acceptance that the climate of southern Africa will be hotter and drier in the future than it is today. By 2050, the average annual temperature is expected to increase by 1.5 to 2.5°C in the south and by 2.5 to 3.0°C in the north compared to the 1961 –1990 average (Ragab & Prudhomme, 2002). Recent model outputs obtained by scientists from the US-based National Centre for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA) revealed "'very clear and dramatic warming of the Indian Ocean into the future, which means more and more drought for southern Africa" (NCAR, 2005).Monsoons across southern Africa could be 10 to 20 percent drier than the 1950–1999 average. Annual regional precipitation is expected to reduce by 10 percent, with greater reductions in the north than in the south (Ragab & Prudhomme, 2002).

2.6.1 Climate change and development in Southern Africa

Climate change and economic development move along in the same direction. Future climate change might affect the economy in southern Africa. According to the United Nations Environment Programme (UNEP) (2006), more than anywhere else, understanding the link between climate change and development is crucial in Africa, where agriculture and other climate sensitive sectors are the mainstay or bedrock of most national economies. The IPCC (2007) reported that yield from rain-fed agriculture could be reduced by up to 50 percent by the year 2020. In many African countries, agricultural production which includes access to food is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition. The climatic hazards that Zambia has experienced so far have severely impacted on agriculture production, food security and other sectors. The food situation is already worrying in southern Africa, with about half of the populations at risk of shortage of food supply. Between 1990 and 2001, the number of undernourished people rose in Botswana, Swaziland and Zambia.Together with South Africa and Zimbabwe, these countries also experienced an increase in child mortality (UNEP, 2006). All these combine to affect the economy of most southern African countries especially a developing country where agriculture is the mainstay of their economic development. The projected future climate will worsen the impacts further with most vulnerable groups being adversely affected socio-economically.

2.7 Climate change awareness

Every day people make decisions in different areas of agriculture and climate change is becoming an increasingly important factor in more and more of these decisions. Climate change awareness needs to be practical in nature and help farmers to deal with productivity and to be able to make decisions that are aligned both with the most reliable available information and their own ethical values. Several research studies have been conducted in various places across the globe to know and determine the level of awareness of people, especially in agriculture and farming activities.

Oruonye (2001) reported an assessment on the level of awareness on the effects of climate change among students of tertiary institutions in Jalingo Metropolis, Taraba State in Nigeria, that there is a low level of climate change awareness among students of tertiary institutions in his study area. Oruonye (2001) further indicated the importance of taking the climate change awareness campaigns to tertiary institutions by encouraging the setting up of climate change awareness clubs. Such clubs can be challenged to identify and find solutions to overcome the almost insurmountable problems of climate change adaptation and mitigation in their locality. This is expected to lead to widespread awareness campaigns, emphasizing the adverse health disorders as a direct result of climate change and its other adverse impacts on socio-economic activities, and also the individual initiatives that can be taken up as well as what the country can do to adapt effectively and mitigate the impact of climate change (Indrani & Purba 2010). Adebayo (2012) indicated that poor resource farmers (maize farmers) have a low level of climate change awareness. For this reason awareness creation is a key measure to address the impact of climate change.

Many people claim to be aware of climate change but in actual fact they are not really aware. Aphunu *et al.* (2012) indicated that, although farmers were aware of the phenomenon, their level of knowledge about the impact of climate change was low. The farmers indicated relying mostly on personal experience rather than on the mass media or extension agents as their main source of information. According to Olayinka *et al.* (2013) despite the fact that the majority indicated various levels of awareness, their understanding of the phenomenon and consequences varied significantly while their knowledge about the causes was generally low.

The Niger Delta region of Nigeria is known to be susceptible to climate change impacts because of its fragile ecosystem and human activities such as gas flaring. A research by Thaddeus *et al.* (2011) indicated that although there is a high level of awareness of climate change in the region, knowledge of Niger Delta farmers on the adverse effects of the changing climate leaves much to be desired. In fact, as much as 60 percent of farmers know little or nothing about climate change and its impacts. Knowledge of climate change impacts is related to availability and accessibility of information on the phenomenon. However, a research conducted on the awareness of climate change on cocoa production in Ghana, established that all cocoa farmers (100 percent) irrespective of their geographical locations were aware about climate change and its multitudinous effect on their farming activities (Francis *et al.,* 2013). When it comes to climate change, many people are already aware of the existence of climate change, and at the same time, they are aware of the impact of climate change.

A study conducted by Sujit and Padaria (2010) in India, showed mixed type of result about awareness level of people in relation to climate change. Though some people were fully aware of climate change, but majority of them lacked detailed information about climate change. However, there is a need for assessment among farmers on climate change. According to Henry (2001) there is a need for these educational campaigns to target females, the poor and the illiterate given that gender, education and income were positive and significant in people's awareness of the importance of climate change. Agricultural extension officers can play an important role in educating the farmers about climate change, mitigation and adaptation. There is need for African nations to include the climate change issue as a vital component of long-term policy and planning, particularly in terms of education and awareness in order that it may be fully appreciated by the general public.

2.8 Summary

In this chapter, literature reveals climate change as a phenomenon which cuts across the entire globe. The literature describes climate change as an average pattern of weather which happens over the long term. An overview of climate change based on international, continental, regional and national levels was given. Many people perceive climate change as periods of extreme heat, droughts and heavy rains, declining rainfall patterns, increasing rise in sea levels, all of which have a great impact on the environment. The causes of climate change and its impact on maize production based on international, continental, regional and national experiences were discussed. The impacts are negative, and are evident in food production and agriculture and in various other sectors, such as health, water resources, ecosystem, shelter, vulnerable populations and national security. The chapter further explains climate change in the study area and the level of awareness in a few countries in Africa.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter focuses on the area where the study took place. It covers the area in square kilometres and the map of the study area. It also explains the population consisting of different ethnic groups found in the province. The chapter also outlines the towns and settlements within the municipal boundaries (Emakhazeni local municipalities situated in the Nkangala district municipality) where the study was conducted. It further covers sampling, data collection, data analysis and the econometric modelling used in the study.

3.2 Study area

The study was carried out in the Mpumalanga province of South Africa. According to the South Africa geographical database (2012), Mpumalanga, is located at -29.8167 latitude and 30.6167 longitude. Mpumalanga lies in the eastern part of the country and it covers a total area of 76 495 square kilometres with an average elevation of 494 meters. It is the second smallest province after Gauteng, taking up 6.3 percent of South Africa's land area and with a population of over 4million people, 4 039 939 to be precise (Census, 2011) 7.8 percent of the share of South Africa's population. Mpumalanga is bordered by the countries of Mozambique and Swaziland to the east and the Gauteng province to the west. It is situated mainly on the high plateau grasslands of the Middleveldt, which roll eastwards for hundreds of kilometres. In the northeast, it rises towards mountain peaks and terminates in an immense escarpment. Almost one third of the population speak isiSwati as in the neighbouring country, Swaziland. IsiZulu, Xitsonga and isiNdebele are commonly heard and also English. Mbombela (previously Nelspruit) is the capital, and the administrative and business hub of Mpumalanga.

According to the national census of 2011, Mpumalanga province has a total number of 21 municipalities, 3 districts and 18 local municipalities. The three district municipalities include Ehlanzeni, Gert Sibande and Nkangala. The Nkangala district municipality consists of 160 towns and villages. The district shares its western borders with the economic hub of South Africa, Gauteng. The district consists of six local municipalities which include the local municipalities of Emalahleni, Steve Tshwete, Emakhazeni, Delmas, Dr JS Moroka and Thembisile. The Emakhazeni local municipality falls under the Nkangala district. Emakhazeni local municipality consists of a population estimated at about 59 000 people in an area of 52 730 hectares (SAI, 2012). The district office is located at Belfast. Towns and settlements within the municipal boundaries include: Airlie, Belfast, Dalmanutha, Dullstroom, Kwaggaskop, Laersdrif, Machadodorp, Nederhorst, Stoffberg, Waterval Boven and Wonderfontein.

An abundance of citrus and many other subtropical fruit, such as mangoes, avocados, litchis, bananas, papaws, granadillas and guavas as well as nuts and a variety of vegetables are produced in Mpumalanga. Mbombela is the second largest citrus-producing area in South Africa and is responsible for one third of the country's export in oranges (SAI, 2012). Groblersdal is an important irrigation area, yielding crops such as citrus, cotton, tobacco, wheat and vegetables. Carolina-Bethal-Ermelo is mainly a sheep-farming area, but potatoes, sunflowers, maize and peanuts are also produced in the region (South African Yearbook, Reviewed, 2012). Crops grown in Mpumalanga include maize, wheat, sorghum, barley, sunflower seed, soybean, groundnut, sugar cane, vegetables, coffee, tea, cotton, tobacco, citrus, subtropical and deciduous fruit.

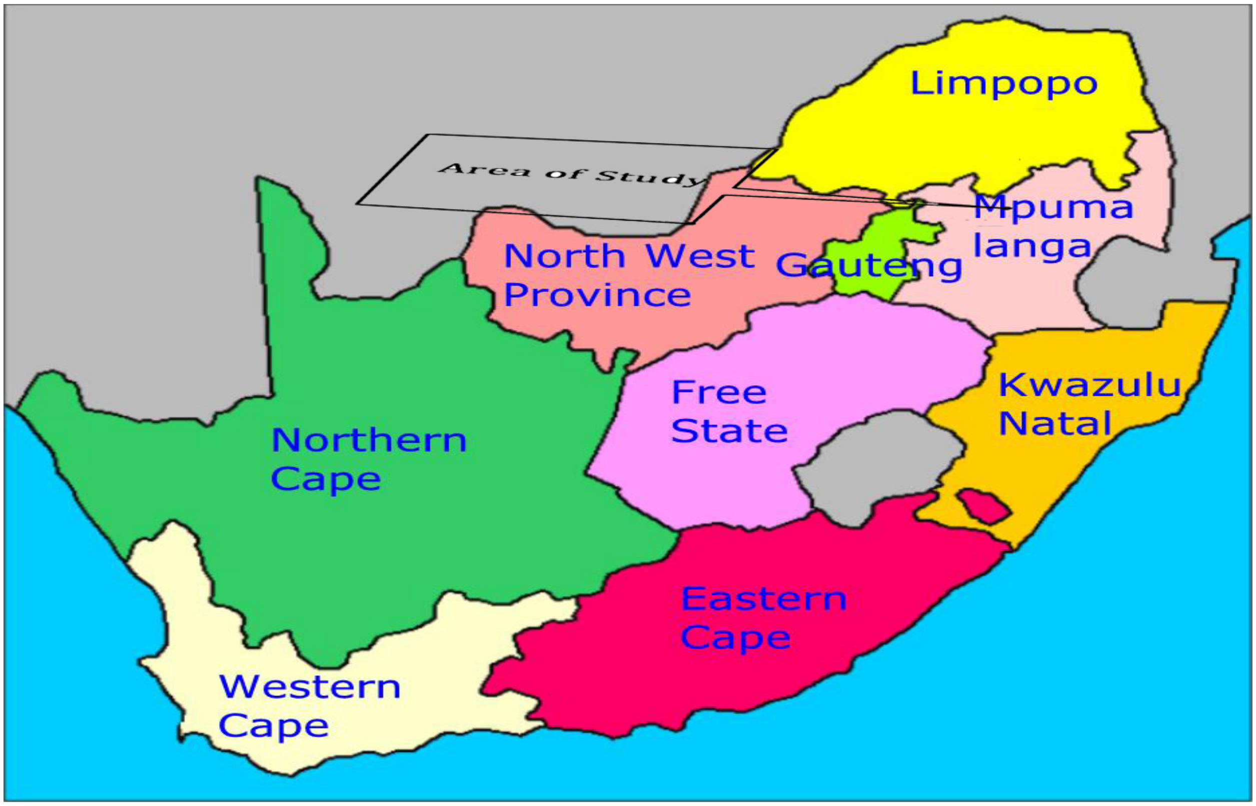

Figure 3.1: Map of study area
Source: South Africa Info (2010)

3.3 Research design

The research was designed in such a way that data were collected from six different towns in Emakhazeni Local Municipality of Nkangala District of Mpumalanga. As show in Table3.1, different numbers of small-scale maize farmers were interviewed using a structured questionnaire based on the numbers of small-scale farmers in each town.

3.4 Data

The data used in the research were primary and secondary data. Primary data was used to collect opinions from the farmers through the use of questionnaires. The questionnaire contains structured questions in which the farmers would have to fill in. The secondary data was used to add other existing evidence and proof to the Primary data that we have collected, through the use of published books and publications, Journals and the internet.

Table 3.1 shows the numbers of farmers in various towns. The towns are across Emakhazeni local municipality in Nkangala District of Mpumalanga. Questionnaires were administered to the farmers according to their total numbers in each town, which was determined through the help of the extension officer.

Table 3.1: Data collection according to selected towns in Emakhazeni local municipality.

Name of towns where data were collected in Emakhazeni local municipality	**Number of respondents (targeted small-scale maize farmers)**
Belfast	50
Dullstroom	45
Machadodorp	40
Nederhorst	30
Stoffberg	30
Waterval Boven	30
Wonderfontein	26

3.5 Sampling technique

Stratified sampling technique was used to select two hundred and fifty one farmers to be interviewed out of over 600 small scale households maize farmers in the six areas. This is a method of sampling which involves the division of a population into smaller groups known as strata. A random sample is then taken in each stratum (Struwig, & Stead, 2001). The strata formed were based on farmers' shared attributes or characteristics.

This sampling was done in such a way that the population was divided across six towns within the Emakhazeni local municipality, in Nkangala district municipality. The sampling was based on the population of small-scale maize farmers in each town and the researcher was informed by the extension officer. The towns included Belfast, Dullstroom, Machadodorp, Nederhorst, Stoffberg, Waterval Boven and Wonderfontein**.** The questionnaires containing matters relating to climate change and agricultural production were used in the interviews. The nature of the research and the contents of the questionnaire were explained to the farmers that were going to be interviewed.

3.6 Data collection procedure

Permission to collect data was granted by the local municipality office to conduct research in various towns within the local municipality. Data was collected through face to face interviews with the farmers where 251 questionnaires were administered in the study area. A well detailed and structured questionnaire written in English was used as a research tool to collect data. The questionnaires were filled in anonymously as no personal questions regarding names, addresses and identity numbers were asked and consisted of a logical flow of questions which address matters relating to climate change and agricultural production. The questionnaire consisted of sections A, B, C and D. Section A was for general information such as the district name, the date of the interview, the characteristics of the household and information on climate change awareness. Section B covered land characteristics while section C covered farmers' observation on climate change. The last section, section D, entailed how productive the maize farmers were in relation to climate change.

3.7 Data analysis

After the data were collected, it was captured and loaded to the application software, Statistical Package for Social Sciences (SPSS) version 20.0 of 2012. This is a software application program that can be used to enable the researcher to perform the task in a simple and easier manner (Vijay, 1999). Data analysis included descriptive statistics compiled from the frequency tables, and further statistical analysis was conducted.

A correlation matrix was done to detect the existence of a relationship between variables in order to make a meaningful prediction. Test of equality of group means was used to identify the significant differences between the means of those groups who are aware of climate change and those groups who were not aware for the variables. Lastly, a binary logistic regression model was used to identify variables that showed a significant difference in the study. Results are in a table format showing the significant of variables in chapter 4.

Table 3.2 shows the expected sign and reasons for the independent variables.

Table 3:2 Expected signs and reasons for the independent variables

Independent variables (X)	Expected signs
Size of the household (X_1)	+
Gender (X_2)	–
Age (X_3)	+
Marital status (X_4)	–
Education (X_5)	+
Occupation (X_6)	+
Source of income (X_7)	–
Information get on climate (X_8)	+
Form of information received (X_9)	+
Any service received (X_{10})	+
Form of extension service received (X_{11})	+
Kind of institutional support received (X_{12})	+
Do you receive institutional support (X_{13})	–
Information make difference (X_{14})	–
What difference made (X_{15})	–
Land tenure system (X_{16})	–
Who owns the farm (X_{17})	–
Who manages the farm (X_{18})	+
Size of the farm (X_{19})	–
Observe temp change (X_{20})	+
Change in rainfall (X_{21})	+
Quantity of harvest in tonnes (X_{22})	+
Has cc affected your production (X_{23})	–
Do you have good seed (X_{24})	–
Profit generated (X_{25})	–

In Table 3.2, the expected sign for household size was positive because large household sizes increase farming activities which tend to increase their awareness of climate change. For gender, the expected sign was negative and this was because gender has no effect on climate change awareness. The expected sign for age was positive, because farmers who are older in age have experience and tend to be more aware of climate change. Marital status was expected to have a negative sign because it has no effect on climate change. The expected sign for education was positive because education plays a role and determines the awareness of climate change. Occupation as a variable was expected to have a positive sign because taking farming as a job leads to awareness of climate change. Source of income has no effect on climate change awareness and it was expected to have a negative sign. Information on climate obtained was expected to have a positive sign because information at farmers' disposal leads to awareness.

The form of information received was expected to be positive because the manner in which information is passed on determines awareness. The expected sign for service received was positive because services rendered by the extension officer determine awareness. The form of extension service received and also the kind of institutional support received were expected to have a positive sign because the type of extension service and the support determine climate change awareness respectively. There were no effects on awareness for the variables such as: what difference information made the land tenure system and who owns the farm, because their expected signs were negative. The expected sign for the variables: who manages the farm, observed temperature change, observed rainfall change and quantity of harvest in tonnes were positive, because a knowledgeable farm manager is aware and that helps to increase the quantity of harvest. The variables such as size of the farm, has climate change affected your production, do you have good seed and the profit generated after planting season were all expected to be negative because they have no effect on climate change awareness.

3.8 Empirical model

Climate change awareness among small-scale maize farmers was determined using SPSS. The SPSS was used in data analysis, descriptive and logistic regression models were used to predict a dependent variable, based on categorical independent variables. The main descriptive indicators that were employed were frequencies and mean values. However, in order to determine the response of climate change awareness by small-scale maize farmers in this study, a binary logistic regression model was applied. Logistic regression is a multivariate technique used to study the relationship between a dichotomous dependent variable and one or more independent variables (Molla-Bauza *et al.,* 2005). A dichotomous variable is a variable that takes only two values, 1 and 0 respectively.

Assuming that climate change awareness is the function of education, age and socio-economic characteristics, the initial model will be given as:

$$\gamma = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k + \varepsilon \qquad (1)$$

Where:

The variable ε is called the error term or disturbance. It is termed “noise” reflecting other factors that influence climate change awareness. It captures the factors other than *x* affecting *y*.

y = dependent variable

Xi = independent variables

β_i = regression coefficients

α = is the constant term

The model for logistic regression analysis assumes that the outcome variable, Y, is categorical (e.g., dichotomous), taking on values of 1 (i.e., yes) and 0 (i.e., no). Hypothetically, population proportion of cases for which Y = 1 is defined as p = P(Y =1). Then, the proportion of cases for which Y = 0 is 1 - p = P(Y = 0). In the absence of other information, we can estimate p by the sample proportion of cases for which Y = 1. However, in the regression context, it is assumed that there is a set of predictor variables, $X_1,...,X_k$, that are related to Y and, therefore, provide additional information for predicting Y.

$$\text{Logit}(P_i) = \ln(P_i / 1-P_i) = \alpha + \beta_1 X_1 + \ldots + \beta_n X_n + {}^{U}t$$

Where:

$\ln(P_i / 1-P_i)$ = logit for farmers awareness choices (Yes or No)

P_i = aware of climate change;

$1 - P_i$ = not aware of climate change;

β = coefficient

X_i = covariates

${}^{U}t$ = error term

When the variables are fitted into the model, the model is presented as:

$$\ln(P_i / 1-P_i) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \ldots + {}^{U}t.$$

3.9 Summary

This chapter provided information about the area where the study took place. It also covered the sample selection techniques in the study area. Data collection and analysis were done. A descriptive statistics was conducted, followed by a correlation matrix. Test of equality of group means was carried out after which a regression models analysis was used to determine the existence of a relationship between variables, in order to make a meaningful prediction on primary data collected from the study area in Emakhazeni local municipality in the Nkangala district, Mpumalanga province, where 251 small-scale maize farmers were interviewed. Variables and the results of the study are further defined in detail in chapter 4.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The aim of the study is to analyse or determine climate change awareness among small-scale maize farmers. Specific objectives were to determine the level of awareness among small-scale farmers, compare the production scale among the farmers who were aware and those who were not, and also to find out the factors which influence the level of farmers' awareness to climate change. However, to achieve the stated objectives, this chapter focused on the results of the study, in which some statistical analysis were done. A descriptive statistics was used to achieve the level of awareness and the level of production scales for both farmers that were aware and those that were not aware. A correlation matrix analysis was done to test the associate variables that had an impact on the level of awareness, while the test of equality of means analysis was done to compare the independent variables between means of groups, of those who are aware of climate change and who are not aware of climate change. And finally, the binary logistic regression model was used to determine the significant variables responsible for the level of awareness between the groups.

4.2 Results

The chapter summarises the variables used in the study in the form of tables. Results were presented for descriptive analysis and inferential analysis.

4.2.1 Descriptive Analysis

Tables and Figures representing the descriptive statistics are shown.

Table 4.1: Distribution of households according to the numbers of years in the farming area

Years	Number of households	Percentages
< 5	129	51.4
6 – 10	88	35.0
11 – 15	30	12.0
16 – 20	4	1.6
Total	**251**	**100.0**

According to Table 4.1, there are 51.4 percent of the farmers that have been farming for the past five years. A larger percentage of farmers in households started farming within the past five years. About 35 percent of the total farmers in households have been in the farming system for 10 years. A very few, about 1.6 percent of the farmers have been farming for 20 years. This shows that there is an increase in farming activities from year to year.

Table 4.2: Distribution of farmers according to the number of towns

Local municipality	Number of households	Percentages
Number of towns		
Belfast	50	19.9
Dullstroom	45	17.9
Machadodorp	40	15.9
Noodgedacht	30	12.0
Stoffberg	30	12.0
Waterval Boven	30	12.0
Wonderfontein	26	10.3
Total	**251**	**100.0**

As reflected in Table 4.2 the following local municipalities were visited: Belfast, Dullstroom, Machadodorp, Noodgedarht, Stoffberg, Waterval Boven and Wonderfontein. These local municipalities were selected according to a stratified sampling technique, which was done in such a way that the population was divided across six towns within the Emakhazeni local municipality, in Nkangala district municipality, based on the population of small-scale maize farmers in each town being informed by the extension officer. The sample frame was designed to meet the objectives of the study and it had to adhere to the statistical specifications for accuracy and representativity. The survey was conducted in from November 2012 to January 2013. The local municipality helped by providing agricultural extension officers who identifying productive farms in various towns mentioned above where questionnaires were administered.

Table 4.3: Distribution of households head according to age

Age group	Number of households	Percentages
16 – 24	12	4.0
25 – 35	30	12.0
36 – 50	122	49.0
51 – 64	82	33.0
65+	5	2.0
Total	**251**	**100.0**

According to Table 4.3 the results indicate that most farmers fall in the age group of 36 – 50+. About 49 percent of the respondents are in this age category. This result corresponds with the findings of Maponya and Mpandeli (2012) who stated that young people in the communities are involved in other activities and use opportunities in the fields of information technology, tendering and jobs in various government departments in the province. The computer age actually enables young people to divert attention from agriculture into information technology and other related professional directions. According to Bayard *et al.* (2007) age is positively related to some climate change adaptation measures, that is, related to agricultural activities. About 2 percent of the farmers fall under the age category of 65+.

Table 4.4: Distribution of households according to gender

Gender	Number of households	Percentages
Male	199	79.3
Female	52	20.7
Total	**251**	**100.0**

Table 4.4 reflects that there are 79.3 percent males compared to 20.7 percent females involved in farming activities in Nkangala district. This indicates that there are more male-headed households in the area. The implication of this finding is that the representation of men is stronger than that of women in farming activities. Women work in agriculture as farmers on their own account, as unpaid workers on family farms. According to FAO (2011) on rural employment and farm labour, it was reported that household and community responsibilities and gender-specific labour requirements also mean that women farmers cannot farm as productively as men. Depending on cultural norms, some farming activities, such as ploughing and spraying, rely on access to male labour without which women farmers face delays that may lead to losses in farm produce. Gender has no significant effect on climate change awareness but on adaptation to climate change (Mandleni, 2011).

Table 4.5: Distribution of households according to size

Size (Persons)	Number of households	Percentages
1– 4	56	22.3
5 – 8	125	49.8
9 –12	56	22.3
12+	14	5.6
Total	**251**	**100.0**

Table 4.5 shows that the majority (49.8%) of the respondents had between five and eight children. This was followed by 22.3 percent of the group who had between one and four children. The large number of children is because most of the small-scale farmers use a large number of households in their faming activities. However, it is likely that these children will be used as source of manual labour in the household.

Table 4.6: Distribution of households according to the levels of education

Education level	Number of households	Percentages
No schooling	72	28.7
Primary education completed	13	5.2
Some secondary education	49	19.5
Secondary education completed	77	30.7
Post secondary education	40	15.9
Total	**251**	**100.0**

As seen in Table 4.6, about 30.7 percent of the farmers in the study completed secondary education, while only a few farmers completed primary education (5.2%). The result shows that the literacy level of the household heads significantly influenced climate change awareness. Previous research by Bayard *et al.* (2007) indicated similar results namely that education significantly, but negatively, affected awareness of climate change. The study by Deressa *et al.* (2009) and Deressa *et al.* (2010) indicate similar results, whereby education of household heads increased the probability of adapting to climate change. Earlier studies (Asfaw & Admassie, 2004; Bamire *et al.,* 2002) reported that education affected agriculture productivity by increasing the ability of farmers to produce more output from given resources and by enhancing the capacity of farmers to obtain and analyse information. It was further emphasised by Maddison (2007) that educated and experienced farmers are expected to have more knowledge and information about climate change and adaptation measures to use in response to climate challenges.

Table 4.7: Distribution of households head according to marital status

Marital status	Number of households	Percentages
Single	23	9.2
Married	164	65.3
Divorced	33	13.1
Widowed	5	2.0
Separated	26	10.4
Total	**251**	**100.0**

The results in Table 4.7 show that 65 percent of the respondents were married, and only 2 percent were widowed. The marital status can influence the extent of the household's farming and can affect the level of climate change awareness through the knowledge of the household head. The more knowledgeable the household head, the more informed and aware the rest of the households would be. According to Mandleni (2011), married livestock farmers were more aware of climate change and adapted to climate change; the possible reason being that they had stayed in the area of study for a reasonable period of time that enabled them to observe climate change which they could pass on to the rest of the household.

Table 4.8: Distribution of households according to occupation

Occupation	Number of households	Percentages
Farming	155	61.8
Employed	58	23.0
Housewife	14	5.6
Pensioner	8	3.2
Business	5	2.0
No occupation	11	4.4
Total	**251**	**100.0**

The major occupation, as seen in Table 4.8, was farming business. 61.8 percent of the respondents engaged in farming as a major occupation. This is because they were small-scale maize farmers who had no other form of occupation except farming. This is supported by Fleshman's (2007) research which estimated that farming, mainly supported by rain in Africa, provided employment to over 70 percent of the labour force.

Table 4.9: Distribution of households according to source of income

Source of income	Number of households	Percentages
Yes	179	71.3
No	72	28.7
Total	**251**	**100.0**

A larger percentage of the respondents received their incomes from maize farming. This shows that maize farming is predominant in Mpumalanga. This is in accordance with the report of the South Africa Grain Laboratory (SAGL, 2008) that stated that Mpumalanga produced 23 percent of the total commercial maize production in South Africa, of which 53 percent was white maize and 47 percent yellow maize. According to the report, Mpumalanga is the second province after Limpopo province, producing maize commercially in South Africa making the province an important contributor to the country's total maize production.

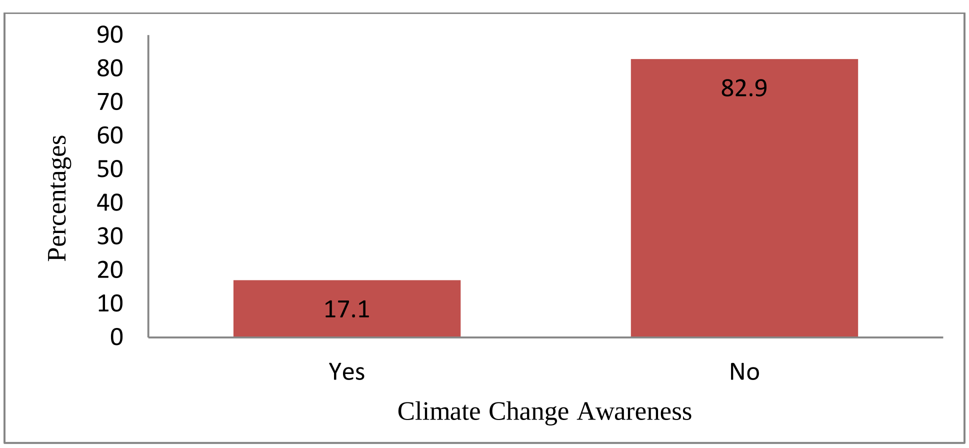

Figure 4.1: Climate change awareness

As shown in Figure 4.1, 82.9 percent of the respondents were not aware of climate change. A total of 17.1 percent of the respondents claimed that they are aware of the climate change as a result of awareness been made in their area. In other words, the majority of the respondents in the sampling area were not aware of the climate change because they claimed that extension officers in the area have not created awareness among them. A similar study conducted by Olayinka *et al.* (2013) revealed that most people still perceived climate change as a result of natural causes and industrialization. The study also indicated that awareness of the various causes of climate change is generally below average. Fewer than 50 percent, however, see it in terms of reduced agricultural productivity or ozone layer depletion; indicating that they are not really aware of climate change.

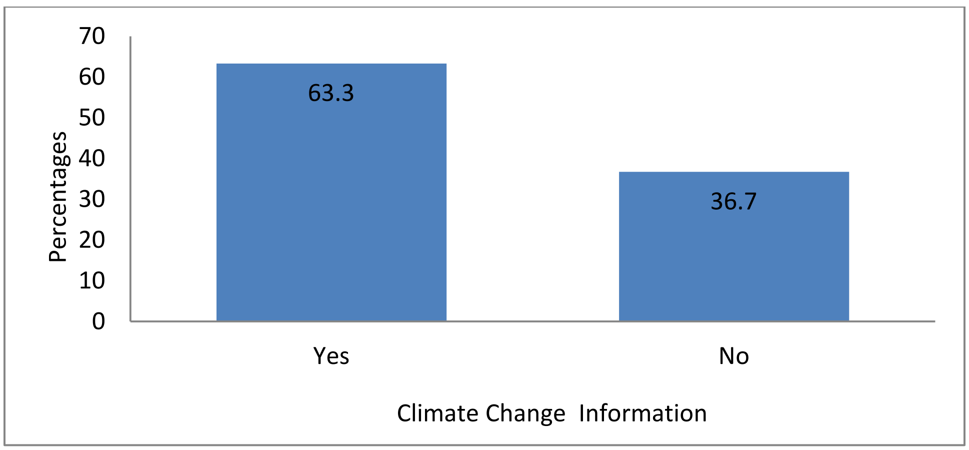

Figure 4.2: Climate change information

Figure 4.2 indicates that only 36.7 percent of the respondents did not receive any information on climate change. On the other hand, 63.3 percent indicated that they received information on climate change through different means available to them. Formal extension positively and significantly affected awareness to climate change and adaptation. The more the farmers had access to extension services and information about climate change, the more they adapted to climate change (Luseno, *et al.,* 2003).

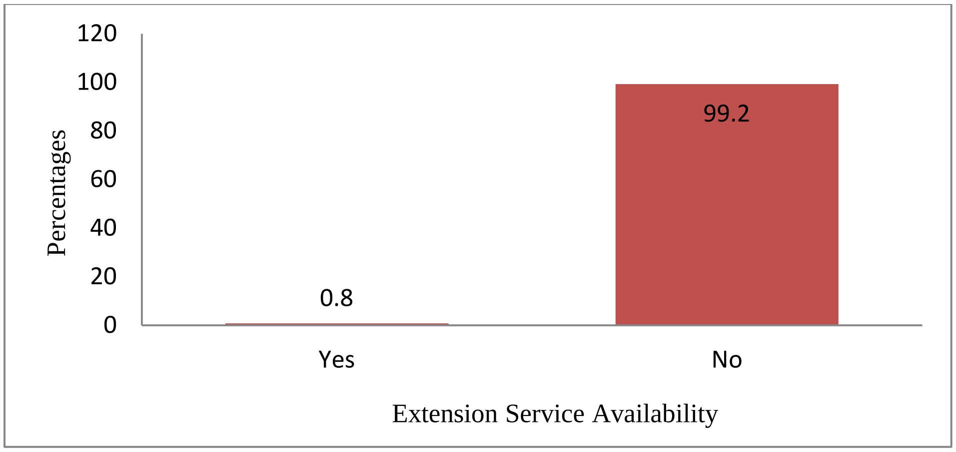

Figure 4.3: Extension service available on climate change issues

As shown in Figure 4.3, about 99.2 percent of the respondents were not getting extension services because these services were not readily available to them. Only 0.8 percent had access to extension service. Similar research conducted by Hassan and Nhemachena (2008), Apata *et al.* (2009), Deressa *et al.* (2010) and Bryan *et al.* (2009) indicated that access to extension services had a strong positive influence on adapting to climate change. Nhemachena (2007) also noted that exposure to extension services influenced the capacity of farmers to adapt to climate change and increases awareness of climate change.

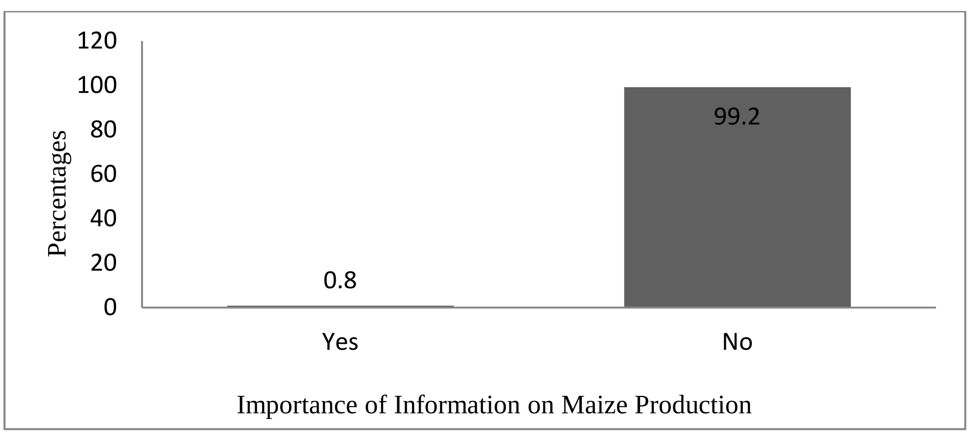

Figure 4.4: Importance of information on maize production

Figure 4.4 indicates that obtaining information made no difference to 99.2 percent of the respondents in their maize farming production. While only 0.8 percent claimed there was a difference in their maize production in relation to the information they received. However, the majority of farmers did not benefit from the information. This result is similar to that of Mandleni and Anim (2011), whereby those livestock farmers who were aware of climate change did not benefit from information about climate change in terms of livestock improvement.

Table 4.10: Distribution of households according to form of extension service

Extension service	Number of households	Percentages
Formal extension	6	2.4
Farmer-to-farmer	232	92.4
Family support	4	1.6
Neighbours	9	3.6
Total	**251**	**100.0**

As reflected in Table 4.10, the major form of extension service available to the farmers is farmer-to-farmer extension service. About 1.6 percent of the respondents received an extension service from family support, 3.6 percent received extension service from the neighbours while the remaining 2.4 percent received extension service from the formal service. According to Mandleni and Anim (2011) formal extension positively and significantly affected awareness of climate change and adaptation. Formal extension must have played a role in informing livestock farmers about climate change.

Table 4.11: Distribution of households according to source of information

Source of information	Number of households	Percentages
Radio	92	36.7
Radio and TV	69	27.5
None	90	35.9
Total	**251**	**100.0**

As indicated in Table 4.11, 36.7 percent of the respondents received climate change information from radio, 27.5 percent from both radio and television and 35.9 percent of the farmers had no source of information. Therefore, the majority use radio as their source of information. This is in accordance with Maponya and Mpandeli (2012) who found that most farmers in rural areas did not have access to other sources of information such as flyers, magazines and the internet and getting information remains a challenge. They were only able to access limited climate change information through local chiefs and the tribal authority.

Table 4.12: Distribution of households according to kinds of institutional support

Institutional support	Number of households	Percentages
Farmer-to-farmer extension	124	49.4
Relatives	2	0.8
None	125	49.8
Total	**251**	**100.0**

Table 4.12 indicated that 49.8 percent of the respondents received no form of institutional support, while 49.4 percent received farmer-to-farmer institutional support. Only 2 percent received institutional support from relatives. This shows that the majority of the farmers received no institutional support. According to research done by Maponya and Mpandeli (2012) more than half of the farmers received no support to adapt them to changing weather patterns, or were even made aware of climate change.

Table 4.13: Distribution of households according to observed Temperature changes

Temperature changes	Number of households	Percentages
Increased temperature	248	98.8
Decreased temperature	1	0.4
No observation	2	0.8
Total	**251**	**100.0**

The respondents observed temperature changes, and it was found that 98.8 percent of the farmers observed an increase in temperature. The result was conformed to Jarraud (2011), "The 2010 data confirm the Earth's significant long-term warming trend," said WMO Secretary-General Michel Jarraud. "The ten warmest years on record have all occurred since 1998." Over the ten years from 2001 to 2010, global temperatures have averaged 0.46°C above the 1961 to1990 average, and are the highest ever recorded for a 10-year period since the beginning of instrumental climate records. Table 4.13, reflects that 0.4 percent of the farmers observed a drop in temperature over the years while only 0.8 percent did not observe or take note of the change either as arise or a drop in temperature over the years.

Table 4.14: Distribution of households according to observed rainfall changes

Extension service	Number of households	Percentages
Increased rainfall	248	98.8
Decreased rainfall	1	0.4
No observation	2	0.8
Total	**251**	**100.0**

Table 4.14 indicates a change in rainfall. It was shown that 98.8 percent of the farmers observed an increase in rainfall. This caused them to have good planting seasons. However, 0.8 percent of the respondents observed a decrease in rainfall, while 0.4 percent did not observe any changes in rainfall. This result is similar to National Science Foundation (2002) that projected an increase in rainfall variability resulting from changes in global climate.

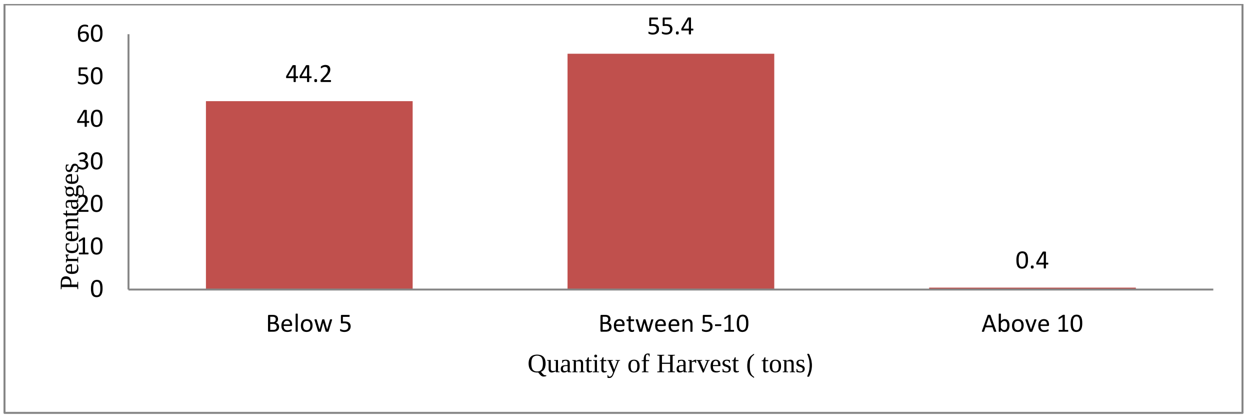

Figure 4.5 Quantity of harvest

Regarding the quantity of harvest, Figure 4.5 indicates that 55.4 percent of the respondents experienced a harvest of between 5 to 10 tonnes per hectare. On the other hand, 44.2 percent had a yield below 5 tonnes per hectare while 0.4 percent has a yield above 10 tonnes per hectare. According to FAO (2005) the average yield of maize in developed countries can reach up to 8.6 tonnes per hectare. The result shows that average farmers have good harvest quantity.

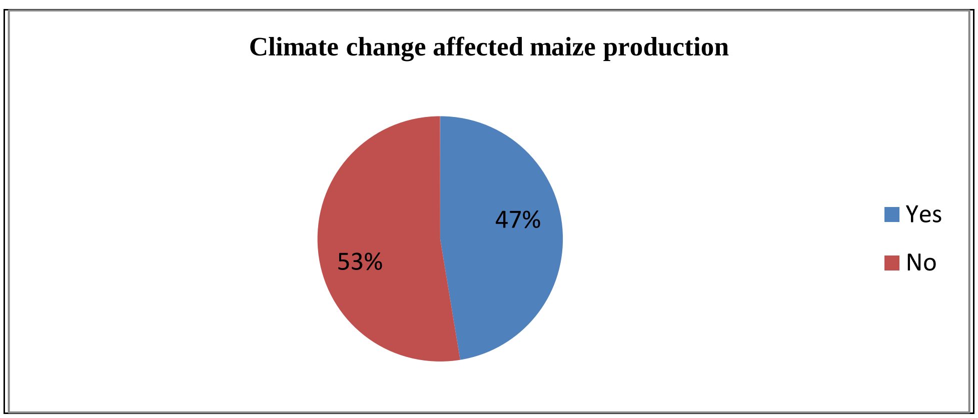

Figure 4.6: Climate change on maize production

As shown in Figure 4.6, 47 percent of the respondents claimed to be affected by the climate change which has an impact on their maize production. However, 53 percent of the farmers were not affected by the climate change; climate change therefore had no impact on their maize farming production. The previous discussion of Figure 4.5 above indicated that they have good quantity of harvest, thus, they were not affected by climate change. This is contrary to Durand *et al.* (2008), who found that maize was highly susceptible to changes in precipitation and temperature.

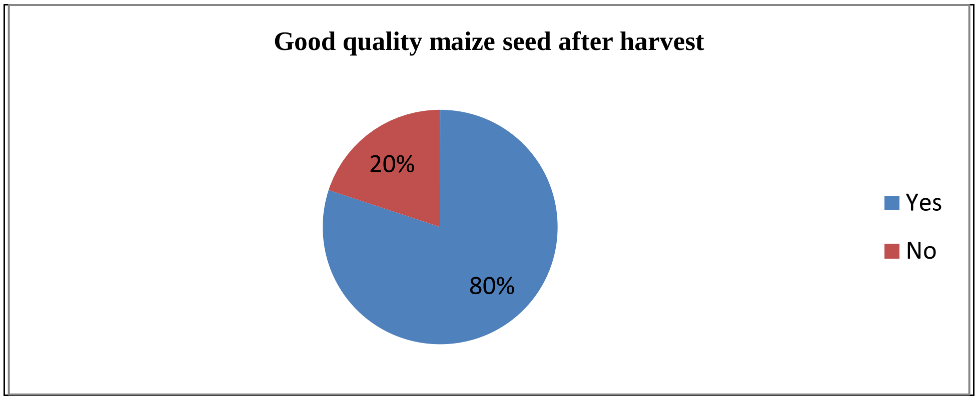

Figure 4.7: Quality maize after harvest

Figure 4:7 above indicates that the majority of farmers (80%) had good quality maize seed after harvest. This could be a result of an increase in the rainfall which helped to yield a good harvest. On the other hand, 20 percent did not have good quality maize seed after harvest. Chi-Chung *et al.* (2004) indicated that precipitation and temperature had opposite effects on yield levels and variability of maize. They further reasoned that more rainfall could cause yield levels to rise, while decreasing yield variance and that temperature had a reverse effect on maize production.

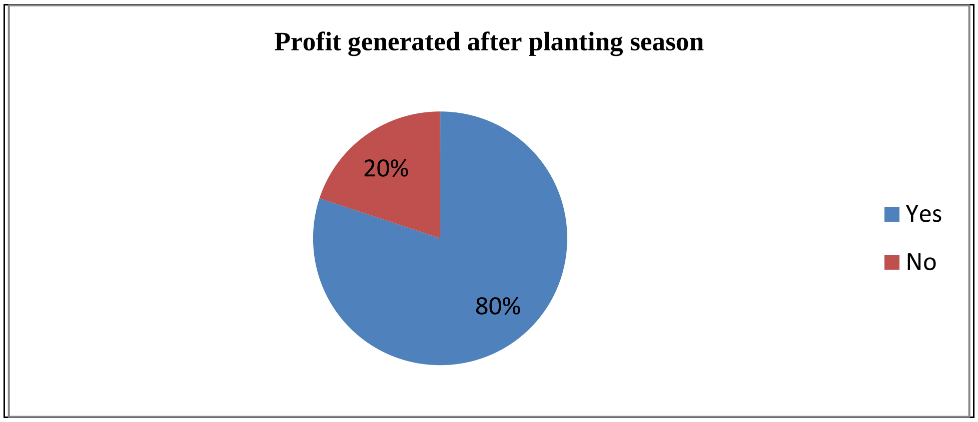

Figure 4.8: Profit generated after planting season

At the end of the planting season, profit was generated as shown in Figure 4.8.A total of 80 percent of the farmers generated profit at the end of the planting season while only 20 percent did not.. This was due to the fact that many farmers had good quality harvest because of the increase in rainfall which supported maize yield.

Table 4.15: Distribution of households according to land tenure system

Land tenure	Number of households	Percentages
Privately owned	79	31.5
Communal land	83	33.0
Permission to occupy (PTO)	69	27.5
Renting	20	8.0
Total	**251**	**100.0**

The land tenure system is controlled mostly by privately owned (31.5 percent) land. As seen in Table 4.15, 8 percent of the land was rented while 33 percent of the land was occupied according to the communal land tenure system. In other words, the majority of the respondents lived on privately owned land as part of the tenure system.

Table 4.16: Distribution of households according to who owns the farm

Farm management	Number of households	Percentages
Individual	84	33.5
Family member	110	43.8
Farmers group	28	11.2
Cooperatives	16	6.4
Private company	13	5.1
Total	**251**	**100.0**

The majority of the farms in Table 4.16 were owned by a family member (43.8%). Individual farm owners consisted of 33.5 percent while private companies own the least, namely 5.1 percent. This shows that family members are the major farm owners.

Table 4.17: Distribution of households according to who owns manage farm

Farm manager	Number of households	Percentages
Individual	151	60.2
Family member	92	36.7
Farmers group	4	1.6
Cooperatives	1	0.4
Private company	1	0.4
Trust	2	0.8
Total	**251**	**100.0**

Table 4:17 indicated that individuals in a household managed the largest proportion of farms (60.2%). Both cooperative and private companies managed individually 0.4 percent, while family members managed 36.7 percent out of the total number of respondents.

Table 4.18: Distribution of households according to farm size

Farm size	Number of households	Percentages
Less than 1ha	2	0.8
>1<2ha	1	0.4
>2<3ha	4	1.6
>3<4ha	2	0.8
>4<5ha	87	34.7
>5 ha and above	155	61.8
Total	**251**	**100.0**

Most of the respondents occupied and farmed on a piece of land which was more than 5 hectare of land (61.8%). While only 0.8 percent farm on a piece of land smaller than 1 hectare. Table 4.18 shows that the majority of the respondents had more than 5 hectares of land to use for their farming activities.

Table 4.19: Descriptive statistics

The descriptive statistics of the variables (dependent and independent variables) used in the model are presented in Table 4.19. Table 4.19, shows the mean values, standard deviation and variance of the dichotomous endogenous variable (aware and not aware) and the exogenous variable used in the binary logistic regression model.

Descriptive statistics Table

Variables	Minimum	Maximum	Mean	Std. Deviation	Variance
Awareness made (X_1) Yes=1; No=0	0	1	0.171	0.378	0.143
Size of the household (X_2) 1-4= 1, 5-8= 2 9-12= 3, >12= 4	1	4	2.112	0.812	0.660
Gender ($X_{3)}$ Male=1, female=2	1	2	1.207	0.406	0.165
Age of the household head (X_4) 20-30=1, 31-40=2, 41-50 = 3 51-60=4. 61-64=5	1	5	3.151	0.835	0.697
Marital status (X_5) Single=1, married=2, Divorced=3 Widow=4, separated=5	1	5	2.390	1.043	1.087
Occupation (X_6) Farming=1, employed=2, Housewife=3 Pensioner=4, no Occupation=6	1	6	1.737	1.272	1.619
Source of income (X_7) Yes= 1, no= 2	1	2	1.287	0.453	0.205
Form of information received (X_8) Fliers=1, magazine=2, Radio=3, local newspaper=4 Others=5, both radio & tv =6, None=7	1	7	5.259	1.767	3.121
Form of ext services received (X_9) Formal extension=1, Farmer-to-farmer=2, Family support=3 Neighbours=4, others=5	1	4	2.064	0.424	0.180
Kind of inst support received (X_{10}) Formal extension=1, Farmer-to-farmer=2, Formal credit=3 Relatives in village=4, Other=5, none=6	1	6	4.008	0.996	3.984
Land tenure system (X_{11}) Private own=1, Communal=2, pto=3 Renting=4, others=5	1	4	2.119	0.947	0.898
Who owns the farm (X_{12}) Individual=1, Family member=2, Farmer groups=3, Cooperative=4 Private company=5, Trust=6, others=7	1	5	2.060	1.081	1.168
Who manages the farm (X_{13}) Individual=1, family=2, Farmer groups=3, Cooperative=4 Private company=5,	1	6	1.466	0.717	0.514

Table 4.19: Descriptive statistics (continued)

Trust=6, others=7					
What is the size of the farm (X_{14}) <1 ha=1, >1<2ha=2, >2<3ha=3, >3<4ha=4 >4<5ha=5, >5 ha and above=6	1	6	5.534	0.755	0.570
Observe change in temp (X_{15}) Increase temp=1 Decrease temp=2, Temp stays the same=3 Not observe=4	1	4	1.028	0.274	0.075
Quantity of harvest produce (X_{16}) Increase temp=1 Decrease temp=2, Temp stays the same=3 Not observe=4	1	3	1.562	0.505	0.255
Good quality seed after harvest (X_{17}) Yes=1, no=2	1	2	1.132	0.339	0.115
Profit at the end of planting (X_{18}) Yes=1, no=2, N/A=3	1	3	1.295	0.633	0.401

Sample Size = 251

4.2.2 Inferential analysis

The inferential analysis was done and the results are presented in Table 4.20

Table: 4. 20: Correlation matrix

Variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
X_1	1.00												
X_2	-0.102	1.00											
X_3	-0.024	-0.228**	1.00										
X_4	-0.095	0.618**	-0.140*	1.00									
X_5	-0.028	0.114	0.167**	0.281**	1.00								
X_6	-0.039	-0.413**	0.245**	-0.345**	-0.151*	1.00							
X_7	0.109	-0.392**	0.110	-0.263**	-0.086	0.284**	1.00						
X_8	-0.169**	0.008	-0.092	-0.024	-0.014	-0.014	-0.043	1.00					
X_9	0.031	-0.067	-0.007	0.029	0.034	-0.036	0.133*	-.065	1.00				
X_{10}	0.030	0.019	-0.002	-0.010	0.087	0.092	0.006	-0.051	-0.001	1.00			
X_{11}	0.121	-0.272**	0.164**	-0.210**	-0.051	0.195**	0.237**	-0.033	0.140*	0.029	1.00		
X_{12}	0.083	-0.108	0.063	-0.090	0.040	0.151*	0.128*	-0.094	0.035	0.081	0.688**	1.00	
X_{13}	-0.045	0.213**	-.168**	0.136*	0.045	-0.176**	-0.216**	-0.045	0.139*	-0.070	-0.065	.098	1.00
X_{14}	0.085	0.287**	-0.245**	0.335**	0.115	-0.316**	-0.262**	0.004	0.093	0.050	-0.050	0.000	-0.144*
X_{15}	0.108	-0.122	-0.052	-0.071	-0.038	-0.013	0.161*	-0.131*	0.157*	0.014	0.018	-0.100	0.076
X_{16}	0.108	-0.122	-0.052	-0.071	-0.038	-0.013	0.161*	-0.131*	0.157*	0.014	0.018	-0.100	0.076
X_{17}	0.011	-0.039	0.063	0.028	0.013	0.053	0.040	-0.091	0.025	0.022	-0.074	-0.109	0.043
X_{18}	0.072	-0.197**	-0.021	-0.024	-0.005	0.032	0.136*	0.014	-0.026	0.125*	-0.179**	-0.172**	-0.119

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table 4.20 shows a correlation or a relationship between climate change awareness and the independent variables, such assize of the household, gender, age of the household head, marital status, occupation, source of income, form of information received, form of extension received, kind of institutional help received, land tenure, who owns the farm, who manages the farm, the size of the farm, observation of changes in temperature and rainfall, good seed, and profit at the end of the planting season. Table 4.20 indicates that a positive relationship between awareness and some other independent variables does exist. Independent variables, such as size of the household, gender, age of the head of the household, marital status, occupation, form of information received, and who manages the farm have a negative association with awareness which indicates an inverse relationship.

Table 4.21: Tests of equality of group means

	Wilks' λ	F-statistic	df1	df2	Sig.
Size of the household	0.990	2.603	1	249	0.108
Gender	0.999	0.140	1	249	0.709
Age of the household head	0.991	2.283	1	249	0.132
Marital status	0.999	0.200	1	249	0.655
Occupation	0.998	0.381	1	249	0.538
Source of income	0.988	2.998	1	249	0.085
Form of information received	0.972	7.298	1	249	0.007
Form of extension services received	0.999	0.246	1	249	0.620
Kind of institutional support received	0.999	0.225	1	249	0.636
Land tenure system	0.985	3.728	1	249	0.055
Who owns the farm?	0.993	1.712	1	249	0.192
Who manages the farm?	0.998	0.505	1	249	0.478
What is the size of the farm?	0.993	1.805	1	249	0.180
Observed change in temperature	0.988	2.950	1	249	0.087
Observe change in rainfall	0.988	2.950	1	249	0.087
Do you have good quality maize seed after harvesting?	1.000	0.029	1	249	0.864
Any profit generated at the end of the planting season?	0.995	1.310	1	249	0.253

N = 251

The results for the tests of the equality of group means carried out for each independent variable are presented in Table 4.21. Here, only one variable (form of information received) differs (Sig. =0.007) for the two groups (aware of climate change and not aware of climate change). This implies that there is a strong statistical evidence of significant differences between means of groups who are aware of climate change and those who are not aware of climate change for the variable (form of information received) with a very high value F-statistics. A test of significance of the group mean explained that the awareness group for the variable (form of information received) was significantly different from the not aware group. However, the rest of the variables for the group that was aware, as shown in the Table 4.21, were not significantly different from the group that was not aware of climate change.

Table 4.22: Binary logistic regression results

Variable	β	S.E.	Wald	d.f	Sig.	Exp(β)
Size of the household	-0.108	0.325	0.111	1	0.739	0.897
Gender	0.020	0.512	0.001	1	0.969	1.020
Age of head of household	-0.355	0.279	1.619	1	0.203	0.701
Marital status	-0.009	0.192	0.002	1	0.964	0.991
Occupation	-0.271	0.209	1.687	1	0.194	0.763
Source of income	0.720	0.480	2.247	1	0.134	2.055
Form of information received	-0.315	0.110	8.248	1	0.004*	0.730
Form of extension service received	-0.205	0.413	0.247	1	0.619	0.814
Kind of institutional support received	-0.004	0.094	0.002	1	0.967	0.996
Land tenure system	0.360	0.271	1.769	1	0.184	1.433
Who owns the farm?	-0.023	0.221	0.010	1	0.919	0.978
Who manages the farm?	-0.175	0.349	0.251	1	0.617	0.840
Size of the farm	0.904	0.438	4.253	1	0.039*	2.470
Observed temp change	0.102	0.562	0.033	1	0.856	1.108
Do you have good seed?	-0.324	0.639	0.257	1	0.612	0.723
Profit generated	0.493	0.324	2.317	1	0.128	1.637
Constant	-4.722	3.122	2.288	1	0.130	0.009

p – values: * $p < 0.05$; ** $p < 0.01$ = Significant at 5% and 1% respectively.

As shown in Table 4.22, there is an association among the following variables in relation to farmers' climate awareness: size of the household, gender, age of the household head, marital status, occupation, source of income, form of information received, form of extension received, kind of institutional support received, land tenure, who owns the farm, who manages the farm, what is the size of the farm, observe temperature changes, observe rainfall changes, good seed, and profit at the end of the planting season.

Household size plays a major role in agriculture especially in small-scale farming. Deressa *et al.* (2011) indicated that a large family size is normally associated with a higher labour endowment which enables a household to accomplish various agricultural tasks. A large household size tends to embark upon labour intensive technology (Featherstone & Goodwin, 1993). The results indicated that household is negative related to climate change awareness and there is no statistical significant difference between the household size and the climate change awareness.

It is widely recognized that climate change does not affect people equally (UNEP, 2011). The related disasters and impacts often intensify existing inequalities, vulnerabilities, economic poverty and unequal power relations (Brody *et al.,* 2008; IPCC, 2007). Differently positioned women and men perceive and experience climate change in diverse ways because of their distinct socially constructed gender roles, responsibilities, status and identities, which result in varied coping strategies and responses (Lambrou & Nelson, 2010; FAO, 2010a). A study by Nhemachena and Hassan (2007) acknowledge women contribution in the agricultural sector in relation to climate change. According to UNDP (2009) across developing countries women's leadership in natural resource management is well recognized. The result showed that gender increased the probability of climate change awareness by 2.0 percent although the coefficient was not significant.

Age is another significant variable associated with climate change awareness. This is not surprising because climate change awareness is made across all age categories even in the schools and out of the school through the use of fliers, posters and other media. Okeye (1998) found that age is positively related to the awareness and adoption of conservation measures. Others, however, found that age is significantly and negatively related to farmers' decision to adopt conservation measures (Gould *et al.,* 1989; Featherstone & Godwin, 1993). The result of this research indicated that age was not significantly and negatively related to climate change awareness. Thus, farmers' age had no significant impact on the awareness of climate change.

Marital status is another variable from the study. According to Aphunu and Nwabeze (2007), it was revealed that the relationship between perception of climate change and marital status was positively correlated and not significantly different. However, this is similar to the result of the study, which indicates that marital status was negatively related to climate change awareness. The likelihood of marital status to climate change decreased by 0.9 percent and was not statistically significant to change in awareness.

Occupation has a significant association with awareness of climate change (Adebayo *et al., 2003*). The more they carried out farming activities, the more they became aware and adapt themselves to climate change. However, the result of the study indicated that there was no significant difference between occupation and climate change.

Source of income is another important variable obtained from the study. Farmers who relied on maize production as a source of income had no other job or extra source of income, than their farming activities. They were involved in and concerned about their environment in relation to their faming activities because they needed to provide for their households. They therefore were more aware of the climate change as an environmental factor responsible for production, unlike farmers who had other sources of income besides farming. This is not surprising because according to Henry (2011) there is a positive relationship between climate change awareness and sources of income.

Evidence from the logistic regression analysis of the study revealed the variable of income source was positively related to climate change, and it was emphasized that a positive sign of a variable indicates that high values of the variables tends to increase the probability of the awareness of climate change. However, the coefficient was not significant to climate change awareness.

The form of information received played a significant role in climate change awareness. Importance of climate change information brought about awareness on climate change and enhanced farmers' knowledge on how to adapt to climate change. Extension education was found to be an important factor motivating increased intensity of use of specific soil and water conservation practices (Bekele and Drake, 2003). However, apart from the fact that information at farmers' disposal brought awareness to climate change, perceived change in climate variables and access to climatic change information are also important pre-conditions to take up adaptation measures (Maddison, 2006). The results of the study indicated that the form of information received had a significant impact on climate change awareness. This could be because most farmers have access to radio, flyers, magazine, the local newspaper, and so forth.

Extension services provided an important source of information on climate change as well as agricultural production and management practices. From the study, the results suggest that the likelihood of the form of extension service received to climate change awareness decreased by 20.5 percent and the coefficient was not significant. This could be because there is little extension services readily available to the farmers. However, Benhin (2006) noted that farmers' level of education and access to extension service are major determinants of adaptation measures to climate change. Improving access to extension services for farmers has the potential to significantly increase farmer awareness of changing climatic conditions as well as adaptation measures in response to climatic changes (IFPRI, 2007).

The kind of institutional support farmers received goes a long way to assist them to increase the level of awareness and to find a measure of adaptation. According to Maponya and Mpandeli (2012) more than half of the farmers received no support to adapt themselves to changing weather patterns, or become aware of climate change. The findings revealed a negative relationship between climate change awareness and the institutional support received by farmers and the likelihood of a decrease of 0.4 per cent with no significant value in climate change awareness. This is because farmers are not getting adequate institutional support that was needed.

The results showed that the land tenure system was positively associated with climate change awareness by 36 per cent but there was no significant difference in awareness. This could be because the majority of farmers followed a privately owned land tenure system and had a small portion of land to farm. So, farmers were not really bothered about awareness because their farm output is small.

The variables related to who owns the farm and who manages the farm have an important role to play in the level of climate change awareness. The two variables involve the farmer and his or her skills or educational level. Many research works have shown that education increased one’s ability to receive, decode and understand information relevant to perception and making innovative decisions (Wozniak, 1984). In addition, Noor (1981) and Omolola (2005) documented the relevance of the literacy level of a farmer to farm productivity and production efficiency. Noor (1981) and Omolola (2005) are of the view that education facilitates farmers’ understanding and use of improved crop technologies. It was emphasized by Maddison (2007) that educated and experienced farmers are expected to have more knowledge and information about climate change and adaptation measures to use in response to climate challenges.

On the contrary, Clay *et al.* (1998) found that education was an insignificant determinant of adoption decisions. However, from the results of the study, who owns the farm and who manages the farm indicated a negative relationship to climate change with a decreased value of 2.3 percent and 17.5 percent respectively, while their coefficients were not significant to the climate change awareness. This outcome could be because individual farmers who owned or managed a farm needed skill enhancement and adequate knowledge about the importance of climate change in order for them to be aware of the climate change.

The variable, size of the farm, was statistically significant in the research study. There is also a positive relationship of 90.4 percent to climate change awareness. This implies that, when the farm size is big, there is a tendency for farmers to be aware of climate change because they are operating on a larger scale. The majority of the farmers have more than 5 hectare of land for their farming activities. On the other hand, contrary to the findings of Mandleni and Anim (2010) who indicated the coefficient was not statistically significant even at the 10 percent level of confidence, though it was positively related to climate change and adaptation.

Precipitation and temperature are found to have opposite effects on yield levels and variability of maize (Chi-Chung *et al.,* 2004). A high rainfall can cause yield levels to rise, while decreasing yield variance and temperature has a reverse effect on maize production.

Observance of changes in temperature and rainfall is another variable which is positively associated with climate change awareness as indicated in the results. There is a positive effect on awareness but the likelihood of observed change in temperature and rainfall varies by 10.2 percent. However, both were not statistically different to awareness. This goes against Ammani *et al.* (2012) who found that rainfall contributes significantly and positively to maize production in the study area despite climate change and awareness

Good seed quality after harvesting is also a variable. The results of the study showed that good quality seed after harvesting was negatively related to climate change awareness and it was not significant to climate change awareness.

The variable, profit generated at the end of the planting season indicated a positive association with climate change awareness. Profit generated at the end of the planting season increased the probability of awareness of climate change by 49.3 percent.

4.3 Summary

This chapter examined the awareness of small-scale maize farmers in the Mpumalanga province in South Africa of climate change. A total number of 251 questionnaires were collected and they were analysed using the descriptive statistics, binary logistic regression models, correlation matrix and test of equality of group means. The results indicated that out of numerous variables analysed using the logistic regression model only a few variables were associated with and significant to climate change awareness.

Table 4:20 showed the correlation matrix of some variables that associated with climate change awareness. The variables were: size of the household, gender, age of the household head, marital status, occupation, source of income, form of information received, form of extension received, kind of institutional received, land tenure, who owns the farm, who manages the farm, what is the size of the farm, observation of temperature changes, observation of rainfall changes, good seed, and profit at the end of the planting season.

The same variables that were associated with awareness were subjected to analysis of the tests of equality of group means' in Table 4:21. The results indicated that only one variable (form of information received) differ (Sig. = 0.007) for the two groups (aware of climate change and not aware of climate change), while the rest of the variables for the aware group, were not significantly different from the not aware group.

The same variables obtained from the correlation matrix analysis were subjected to the binary logistic regression model where only two variables (form of information received and size of the farm) were statistically significant to climate change awareness. Though the remaining variables were not statistically significant to climate change awareness some were positively associated with awareness while others were negatively related.

It was concluded in this chapter that the two significant variables or factors mentioned above are important constraints to climate change awareness. Addressing these issues could significantly help farmers to be aware of climate change.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 Introduction

The scientific community widely agreed that climate variability and change is already a reality (IPCC, 2007). According to Maponya and Mpandeli (2012) climate variability and change are also likely to increase the frequency and magnitude of extreme weather conditions such as droughts, floods and storms. They provide an example mentioning the Limpopo province where some of these weather conditions, when floods in January 2000 and early in January 2012 destroyed crops and infrastructure, and affected the harvest. Mandleni (2011) reported that awareness of climate change in many studies has been of great concern. Many examples in the literature confirm that climate change awareness played a significant role in agriculture because it strengthened farmers' productivity and increased food production. This final chapter is aimed at discussing the major findings in summary form, add a conclusion and make recommendations.

5.2 Conclusion

This study is intended to contribute to the body of knowledge on climate change awareness by small-scale maize farmers. The study was conducted in the Emakhazeni local municipality in the Nkangala district, Mpumlanga province of South Africa. The objectives of the study as outlined in chapter 1 are to:

(a) determine the level of awareness of small-scale maize farmers in response to climate changes

(b) compare the level of production scale between the farmers who are aware and the farmers who are unaware of climate change

(c) find out the factors that influence the level of farmers' awareness of climate change

To achieve the objectives of this study, a comprehensive literature review on the concept and understanding of climate change was made. The literature also focused on climate system and causes of climate change, the impact of climate change on agriculture and food (maize production in particular), ecosystem and health. It also revealed the level of climate change awareness (across the globe, region and locally), future climate change and development in southern Africa. The study was conducted in Nkangala district municipality, Mpumalanga province of South Africa. Data was collected by way of questionnaires involving interviews with 251 small-scale maize farmers. The binary logistic regression model was used to analyse the data. The model identified a few independent variables which had a significant impact on climate change awareness.

5.2.1 Results summary

This section shows the results of the study. However, from the findings made, the level of awareness in response to climate change by small-scale maize farmers in the study area is 17.1 percent. This shows that the level of awareness is low compared to the level of unawareness (82.9%). This could be because extension services are not always available to them. Lack of exposure to extension service influences awareness, just as fund by Nhemachena (2007). Though many farmers claimed to receive information through different means it is not a formal extension. The percentage of formal extension is 2.4 percent. This confirms findings of Mandleni (2011) that formal extension positively and significantly affected awareness to climate change and adaptation.

According to the findings that were achieved in respect of the second objective, in comparison to production scales between the farmers who are aware and the farmers who are not aware. The majority of farmers (80%) had good quality maize seed and the same proportion of the farmers generated profits at the end of the planting season.

Good quality maize seeds during harvest enticed good profits. The reason is not far fetched because there is an increase in rainfall and this aids good harvest. Chi-Chung *et al.,* (2004) indicated that precipitation and temperature were found to have opposite effects on yield levels and variability of maize and that, more rainfall could cause yield levels to rise.

The third objective indicated factors which influenced the level of farmers' awareness of climate change. This research highlighted a correlation or a relationship between climate change awareness and the independent variables, size of the household, gender, age of the household head, marital status, occupation, source of income, form of information received, form of extension received, kind of institutional received, land tenure, who owns the farm, who manages the farm, the size of the farm, observe temperature changes, observe rainfall changes, good seed and profit at the end of the planting season as explained in Table 4.20.

However, seen from the binary logistic regression model, the variables (form of information received and the size of the farm) were significant in the study. The research showed that if the two factors mentioned were critically addressed, the level of climate change awareness could be greatly influenced in a positive way and likewise other variables that were associated with climate change awareness.

5.3 Recommendations

A number of recommendations arise from this research and these recommendations could be considered by Mpumalanga province's department of agriculture and other key stakeholders who are interested in climate change issues, and may require further research. The recommendations should be based on information given to the farmers on climate change, its awareness and how it is been disseminated.

5.3.1 Use extension services

Farmers should not underestimate the role of agriculture extension officers. Their role should be properly communicated to the farmers so that they can embrace the opportunity of having extension agents around them. The service could include: teaching farmers about the adoption of new innovations and technology, and environmental issues and improving farmers' skills and farming methods.

The extension officer should find it worthy to assist the farmers by disseminating knowledge and information needed by the farmer such as climate change information, lectures on subject-related issues on various farming activities. Extension officers could also organise group meetings with the farmers to increase their morale, group demonstration and participation.

A policy that aims to foster and coordinate an effective extension service among the farmers in the communities should be designed and introduced by the extension officer and the government so as to improve the information on climate change awareness, and other areas in which information are needed.

5.3.2 Education on climate change

Accurate knowledge about the importance of climate change should be disseminated to the farmers in order for them to know what climate change is all about and what impact is has on their farming activities. A proper education will bring about an increase in their level of awareness. Farmers should be equipped with knowledge on climate change, vulnerability and the adaptation of measures to help them in their faming activities. Different forms of information could be passed on using various sources such as print and electronic media, and audio and visual aids. Research institutions such as the Agricultural Research Council and civil societies (NGOs) could help with the dissemination of facts about climate change.

5.3.3 Government policy

Government policies should address the need to support the training of extension officers so that they are given relevant information about climate change awareness and skills required by the farming communities. They should be equipped with the necessary skills to disseminate information in a simple manner that farmers will understand.

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APPENDIX

QUESTIONNAIRE

CLIMATE CHANGE AWARENESS: A CASE STUDY OF SMALL-SCALE MAIZE FARMERS IN MPUMALANGA PROVINCE, SOUTH AFRICA.

N.B This information is confidential and is between the interviewer and the respondent.

DATE: …………………………………………………………………………………………..

NAME OF INTEVIEWER: ……………………………………………………………………

HOW LONG HAS THE HOUSEHOLD BEEN IN THE AREA? ……………………………

DISTRICT MUNICIPALITY (please tick the appropriate box):

1. Nkangala	2. Ehlanzeni	3. Gert Sibande

LOCAL MUNICIPALITY: ……………. Emakhazeni local municipality

WARD: …………………………………………

A. COMPOSITION AND CHARACTERISTICS OF HOUSEHOLD

Please fill in the household characteristics information with the interviewee.

A.1 FARM HOUSEHOLD CHARACTERISTICS

1	2	3	4	5	6	7
Size of household	**Gender of head of household**	**Age of head of household (years)**	**What is marital status of the household head?**	**Education level**	**Occupation**	**Is maize farming your major source of income**
	Male……….1 Female…….2	20-30……..1 31-40……..2 41-50……..3 51-60……..4 61-64……..5	Single………..1 Married………2 Divorced……..3 Widowed……..4 Separated..…...5	Pre-school…….1 Up to …………..2 Std 6..………....3 Standard10…….4 Higher…..........5 None..………....6	Farming………….1 Employed………...2 Housewife…........3 Pensioner………...4 Business………….5 No occupation …..6	Yes………..1 No…………2

A.2 ACCESS / AWARENESS TO INFORMATION ON CLIMATE CHANGE

A.2.1 Is there any awareness being made in your area on climate change?

Yes …………………….1

No………………………2

A. 2.2 Is there any information that you get on climate change?

Yes ……………………..1

No………….……………2

A.2.3 What form of information do you receive on climate change?

1. Flyers	2. Magazines	3. Radio	4. Local newspapers	5.Other (specify) ……………	6. None

A. 2.4 Is there any extension service that you receive on climate change?

Yes ……………………1

No……………………2

A.2.5 What form of extension services do you receive on climate change?

1.Formal extension	2.Farmer-to-farmer	3.Family support	4.Neighbours	5.Other (specify) …………………………

A.2.6 What kind of institutional support do you receive for climate change effects?

1. Formal extension	2. Farmer-to-farmer extension	3. Formal credit	4. Relatives in the village	5. Other (specify)	6. None

A 2.6 Do you receive any institutional support about climate change?

Yes……..1
No……….2

A.2.7 What kind of institutional support do you receive for climate change effects?

1.Formal extension	2.Farmer-to-farmer extension	3.Formal credit	4.Relatives in the village	5.Other (specify)	6.None

A.2.8 Does the information you get make any difference in your maize farming production?

Yes ……………………1

No……………………2

A.2.9 What difference is made by the information received? List them

B. LAND CHARACTERISTICS

B.1 Land tenure system

1. Private (own)	2. Communal	3. Permission to occupy (P.T.O)	4. Renting	5. Other (specify) ………………………

C. 2 Who owns the farm?

1.Individual	2.Family members	3.Farmers' group	4.Co operative	5.Private company	6.Trust	7. Other (specify) ………………………………

D. 3 Who manages the farm?

1. Individual	2. Family members	3.Farmers' group	4.Co operative	5.Private company	6.Trust	7. Other (specify) ………………………………

B. 4 Size of the farm?

1.Less than 1ha	2.More than 1but below 2ha	3. .More than 2 but below 3ha	4. .More than 3 but below 4ha	5. .More than 4 but below 5ha	6. .More than 5 ha and above

C. FARMERS' OBSERVATIONS ON CLIMATE CHANGE

C.1 Do you observe any climatic changes? Tick in the relevant box.

a) Changes in temperatures:

1.Temperatures increased	2.Temperatures decreased	3.Temperatures stayed the same	4. Not observed any changes in temperatures

b) Changes in rainfall:

1.Rains increased	2.Rains decreased	3.Rains stayed the same	4. Not observed any changes in rainfall patterns	5. Floods

C.2 What can you say about the weather over the past 5 years?

	Drought	Winds	Floods	Fire	Other (specify)
2011					
2010					
2009					
2008					
2007					

E. MAIZE PRODUCTION

D.1 What can you say about the quantity of you r harvest in tonnes per hectare at the end of the planting season?

Below 5 tonnes…….1
Above 5 tonnes below 10 tonnes …….2
Above 10 tonnes……………..3

D.2 Can you say that climate change has affected your maize production?

Yes…………………….…1
No……………………..…..2

D.3 Do you have good quality maize seed after harvest?

Yes…………………….…1
No……………………..…..2

D.4 Is there any profit generated at the end of the planting season?

Yes…………………….….1
No……………………..…..2
N/A……………………..3

Thank you for answering this questionnaire

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