

Climate Change and Agricultural Production in Limpopo Province: Impacts and Adaptation
Options

by

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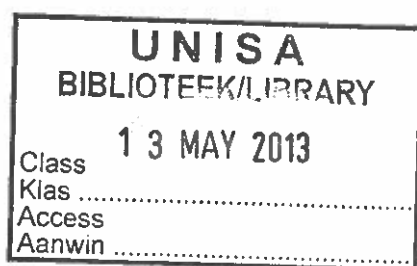
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DEDICATIONS

This study is dedicated to my wife Mma Matome and children Dimakatso, Maropeng and Amogelang.

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DECLARATION

I, Phokele Maponya, declare that this is my work. It is submitted for the degree of Doctor of Philosophy in Environmental Management at the University of South Africa. The work has not been submitted before for any degree or examination at any other university.



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ABSTRACT

The primary aim of my research was to identify the impacts and adaptation options of climate variability and change on agricultural production in Limpopo province. The following objectives were identified: To understand the impacts of climate variability and change on agricultural production in Limpopo province , To assess the impacts of climate variability and change on agricultural production in Limpopo province and To identify adaptation measures that reduces the impacts of climate variability and change on agricultural production in Limpopo province. A representative sample of 300 farmers aged 16 – 65+ years (46 percent males and 54 percent females) participated in the study. The study involved Sekhukhune and Capricorn districts, with 56 percent farmers in Capricorn and 44 percent in Sekhukhune district. The following 11 local municipalities were visited: *Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane, and Molemole.*

The Limpopo province is one of the poorest provinces in the country, characterized by high unemployment rate, poverty and lack of access to a range of resources that frustrate majority of people ability to secure their livelihoods. In this study the province's economic, biological and physical environment were highlighted. The study further covers the province's farming enterprises, systems, categories, infrastructure as well as other constraints that maybe facing the emerging farmer in the province.

It is assumed that the majority of farmers in both the Capricorn and Sekhukhune districts are using different coping and adaptation strategies in order to increase their crop yields. Literature studies show that climate variability and change adaptation strategies vary from area to area due to agro ecological zones and the harshness of the effects of climate variability and change. It has also been noted that climate change is fast pushing the poorest and most marginalized communities beyond their capacity to respond. This study draws on lessons learned, experiences, and other existing research on climate change impacts and adaptation across the globe. It sets out what is needed to enable people living in poverty to adapt to climate change, and a range of interventions that are available across climate – sensitive sectors.

The study has provided a literature review of the impact of climate change on the agricultural sector. In fact, it has documented some of the likely impacts of climate change based on International, continental, regional, national and provincial agricultural sector. The study highlighted the impact of climate change also on various climate – sensitive sectors including understanding water resources, forestry, natural ecosystem human health, infrastructure and coastal zones. This research also confirmed that being a full time farmer, gender, information on climate change, information received through extension services and adaptation to climate change are some of the important determinants of agricultural production, food scarcity and unemployment. A worrying situation is reviewed globally in this study and it can be concluded that climate variability and change is affecting every sector in society and it needs urgent attention. Statistics was used to determine climate variability and change impact on agricultural production. Results indicate that farmers are aware that Limpopo province is getting warmer and drier with increased frequency of droughts, changes in the timing of rains, observed trends of temperature and precipitation.

The study also presented perceived adaptation strategies used by farmers in Limpopo province. Some of their perceived adaptation strategies included: (a) Soil management strategies, (b) Water management strategies and (c) Others like use of subsidies and use of insurance. Other important adaptation options being used by farmers were also discussed in this study including different adaptation measures against colds, heat, frost, abnormal wind, hail, lack of extension support, nematodes, insecticides, worms, temperature and rainfall. The results of this study are potentially valuable to the agricultural sector considering the threats that climate change poses across climate sensitive sectors.

Keywords: Climate variability, climate change, agricultural production, Limpopo, South Africa

TABLE OF CONTENTS

DEDICATIONS	i
DECLARATION.....	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	v
TABLE OF CONTENTS.....	vii
LIST OF FIGURES	xii
LIST OF PICTURES	xii
LIST OF TABLES	xiv
 CHAPTER 1	 1
1.1 Introduction	1
1.2 Research Problem	3
1.3 Hypothesis.....	3
1.4 Aims and Objectives.....	4
1.4.1 Aim.....	4
1.4.2 Objectives.....	4
1.5 Significance of the study	4
1.6. Research methodology	5
1.6.1 Study sites are (a) Greater Sekhukhune and Capricorn districts in Limpopo province....	5
1.6.2 Data collection, sampling and analysis.....	6
1.7 Summary	7
 CHAPTER 2	 8
Theoretical and empirical studies relating to climate change adaptation	8
2.1 Introduction.....	8
2.2 Impact of climate change in various sectors across the globe	9
2.2.1 Water resource based on international perspective.....	9
2.2.2 Water Resource based on continental perspective.....	12
2.2.3 Water Resource based on regional perspective	13
2.2.4 Water Resource based on national and provincial perspectives.....	14
2.2.5 Ecosystem and biodiversity based on international perspective	17
2.2.6 Ecosystem and biodiversity based on continental perspective	19
2.2.7 Ecosystem and biodiversity based on regional perspective.....	19
2.2.8 Ecosystem, Forestry and biodiversity based on national and provincial perspectives..	20
2.2.9 Infrastructure based on continental perspective	21

2.2.10 Infrastructure based on regional perspective.....	22
2.2.11 Infrastructure based on national and provincial perspectives	23
2.2.12 Coastal zones issues based on international perspective	24
2.2.13 Coastal zone issues based on continental perspective	26
2.2.14 Coastal zones issues based on regional perspective.....	27
2.2.15 Coastal zones issues based on national and provincial perspectives	28
2.2.16 Health issues based on international perspective	29
2.2.17 Health issues based on continental perspective	32
2.2.18 Health issues based on regional perspective.....	32
2.2.19 Health issues based on national and provincial perspectives	33
2.3 Impact of climate change on livestock, crop yields and crop prices	35
2.3.1 Climate change impacts on livestock production based on international perspective...35	
2.3.2 Climate change impacts on livestock production based on continental perspective.....36	
2.3.3 Climate change impacts on livestock production based on regional perspective	37
2.3.4 Climate change impacts on livestock production based on national perspective	38
2.3.5 Climate change impacts on livestock production based on provincial perspective	39
2.3.6 Climate change impacts on crop yields based on continental perspective.....39	
2.3.7 Climate change impacts on crop yields based on regional perspective	40
2.3.8 Climate change impacts on crop yields based on national perspective.....40	
2.3.9 Climate change impacts on crop yields based on provincial perspective	42
2.3.10 Impacts of climate change on crop prices based on continental perspective	42
2.3.11 Impacts of climate change on crop prices based on regional perspective.....43	
2.3.12 Impacts of climate change on crop prices based on national perspective.....43	
2.3.13 Impacts of climate change on crop prices based on provincial perspective.....44	
2.4 Impacts of climate change on food security and farm income	44
2.4.1 Impacts of climate change on food security based on continental perspective	44
2.4.2 Impacts of climate change on food security based on regional perspective.....45	
2.4.3 Impacts of climate change on food security based on national perspective	46
2.4.4 Impacts of climate change on food security based on provincial perspective.....47	
2.4.5 Impact of climate change on farm income based on continental perspective	47
2.4.6 Impact of climate change on farm income based on regional perspective.....47	
2.4.7 Impact of climate change on farm income based on national perspective	48
2.4.8 Impact of climate change on farm income based on provincial perspective.....48	
2.5 Summary	49

CHAPTER 3	52
Overview of the agricultural activities in Limpopo province	52
3.1 Introduction	52
3.3 General overview of the physical environment in Limpopo province	53
3.4 General overview of the biological environment in Limpopo province	53
3.5 Farming enterprises in the Limpopo province	54
3.6 Farming systems in the Limpopo province	55
3.7 Farms categories in Limpopo province	56
3.7.1 <i>Commercial farms</i>	56
3.7.2 <i>Small scale farms</i>	56
3.7.2.1 <i>Emerging commercial farms</i>	56
3.7.2.2 <i>Subsistence farms / Resource poor farms</i>	56
3.8 Infrastructure in the Limpopo province	56
3.9 Constraints and challenges facing farmers in Limpopo province	57
3.10 Socio economic situation context in Limpopo province	57
3.10.1 <i>Basic social indicators</i>	59
3.10.2 <i>Demographic and economic indicators in South Africa</i>	61
3.11 Health and welfare issues in Sekhukhune District	68
3.12 Health and welfare issues in Capricorn District	69
3.13 Biophysical factors in Sekhukhune District	70
3.13.1 <i>Climate</i>	70
3.13.2 <i>Topography</i>	74
3.13.3 <i>Soils</i>	74
3.13.4 <i>Geology</i>	74
3.13.5 <i>Air quality</i>	75
3.13.6 <i>Water</i>	75
3.14 Biophysical factors in Capricorn District	76
3.14.1 <i>Climate</i>	76
3.14.2 <i>Topography</i>	77
3.14.3 <i>Soils</i>	78
3.14.4 <i>Geology</i>	78
3.14.5 <i>Air quality</i>	78
3.14.6 <i>Water</i>	78
3.15 Summary	79

CHAPTER 4	81
Measuring the impact of climate variability and change on agricultural production in Limpopo province.....	81
4.1 Introduction	81
4.2 Characteristics of sample.....	81
4.3 Socio economic characteristics of farmers	83
4.4 Farmers response to climate variability and change: Impact on their livelihoods.....	95
4.5 Farmers response to climate variability and change: Impact on agricultural production....	96
4.6 Farmers response to climate variability and change: Impact on Food security	96
4.7 Univariate analysis model.	97
4.8 Summary	104
 CHAPTER 5	 105
Climate variability and change in Limpopo province	105
5.1 Introduction	105
5.2 Climate variability and change in Capricorn District.....	105
5.3 Climate variability and change in Sekhukhune District.....	107
5.4 Drought impacts in the Limpopo province.....	107
5.5 Agricultural activities in Sekhukhune District.....	111
5.6 Agricultural activities in Capricorn District.....	112
5.7 Agricultural infrastructure in the Limpopo province	113
5.8 Agricultural infrastructure in Sekhukhune District	113
5.9 Agricultural infrastructure in Capricorn District	114
5.10 Adaptation of farmers to climate change, variability and drought in Limpopo province	114
5.11 Summary	117
 CHAPTER 6	 119
Determinants of climate variability and change adaptation strategies of selected Limpopo province farmers	119
6.1 Introduction	119
6.2 Perceived barriers to adaptation in Limpopo province.....	122
6.3 Climate change adaptation measures used by some farmers in Limpopo Province.....	123
(a) <i>Colds, Heat, Frost, Abnormal Wind and Hail</i>	123
(b) <i>Extension Support Services</i>	124

(c) <i>Rainfall</i>	125
(d) <i>Drought</i>	125
(e) <i>Temperature</i>	128
(f) <i>Nematodes, Insecticides and Worms</i>	129
6.4 <i>Summary</i>	129
 CHAPTER 7	131
7.1 <i>Conclusions and Recommendations</i>	131
7.2 <i>Understanding the impacts of climate variability and change</i>	132
7.3 <i>Assessing the impacts of climate variability and change</i>	134
7.4 <i>Identification of adaptation measures that reduces the impacts of climate variability and change</i>	138
7.5 <i>Recommendations</i>	138
7.5.1 <i>Information about climate change</i>	139
7.5.2 <i>Adaptation to climate change</i>	139
7.5.3 <i>Information dissemination through extension services</i>	140
7.5.4 <i>Drought</i>	140
7.5.5 <i>Indigenous coping strategies</i>	140
7.5.6 <i>Crop diversification</i>	140
 REFERENCES	142
 APPENDIX A : QUESTIONNAIRE	169
APPENDIX B: CONSENT FORM	178
APPENDIX C: UNISA ETHICS APPLICATION OUTCOME	181
APPENDIX D: LETTER FROM HEAD OF DEPARTMENT	183
APPENDIX E: PAPER PRESENTATION	184
APPENDIX F: PAPER ACCEPTED	184
APPENDIX G: PAPER ACCEPTED	186
APPENDIX H: PAPER UNDER REVIEW	187
APPENDIX I: PAPER ACCEPTED	188
APPENDIX J: PAPER ACCEPTED	188
APPENDIX K: PAPER PRESENTATION	190

LIST OF FIGURES

Figure 1.1: Geographic location of the Greater Sekhukhune and Capricorn Districts in Limpopo province..... 6

Figure 3.1: Rainfall Distribution in Limpopo province (1980 – 2009)..... 71

Figure 3.2: Rainfall Outlook in Limpopo province: May – July 2012 72

Figure 3.3: Rainfall Outlook in Limpopo province: July – September 2012 72

Figure 3.4: Sekhukhune District Monthly Average Temperature - 1983 – 2008..... 73

Figure 3.5: Capricorn District Monthly Average Temperature - 1983 – 2008..... 76

Figure 3.6: Temperature Outlook in Limpopo province: June – August 2012 77

Figure 4.1: Gender of farmers 84

Figure 4.2: Types of farms in both Capricorn and Sekhukhune Districts 86

Figure 4.3: Farm management in both Capricorn and Sekhukhune Districts 86

Figure 4.4: Farm ownership in both Capricorn and Sekhukhune Districts 87

Figure 4.5: Farm acquisition in both Capricorn and Sekhukhune Districts..... 88

Figure 4.6: Sources of information on climate change 88

Figure 4.7: Access to Extension Officer..... 89

Figure 4.8: Support on climate change impact..... 89

Figure 4.9: Perception on long term temperature changes 90

Figure 4.10: Farmers perception on precipitation changes..... 91

Figure 4.11: Adaptation to climate change..... 91

Figure 4.12: Climate change impact on agricultural production..... 92

Figure 4.13: Employment status in both Capricorn and Sekhukhune Districts..... 98

Figure 5.1: Current experience on weather patterns in Limpopo Province 109

LIST OF PICTURES

Picture 4.1 Questionnaire 82

Picture 4.2 Focus group discussions at Aganang local municipality – 22 September 2011 83

Picture 4.3 Chillies damaged by increased temperature in Capricorn District, Limpopo province ...
.....92

Picture 4.4 Onions damaged by increased temperature in Capricorn District, Limpopo province
.....93

Picture 4.5 Maize damaged by frost/hail in Sekhukhune District, Limpopo province 93

Picture 4.6 Butternuts damaged by hail in Sekhukhune District, Limpopo province 94

Picture 4.7 Farmer showing tomatoes damaged by hail and high temperatures in Limpopo
province..... 94

Picture 5.1 Drought impact in Limpopo province 108

Picture 5.2 Drought impact in Limpopo province 110

Picture 6.1 Nets / shades as adaptation measure against cold and heat conditions 123

Picture 6.2 Wood serving as adaptation measure against abnormal winds 124

Picture 6.3 Minimum tillage practice by farmers in Limpopo Province 126

Picture 6.4 Water harvesting and optimization practice by farmers in Limpopo Province and other
parts of the country..... 126

Picture 6.5 Multi cropping and rotation practice by farmers in Limpopo Province and other parts
of the country. 127

Picture 6.6 Mulching system practiced by framers in Limpopo Province and other parts of the
country.....127

Picture 6.7 Environment monitoring tool – rain gauge..... 128

LIST OF TABLES

Table 3.1 A comparison of social indicators for South Africa and Limpopo province	58
Table 3.2 Population distribution by municipality – Community survey 2007	60
Table 3.3 Unemployment rate in Limpopo Province as compared to other Provinces in South Africa.....	61
Table 3.4 Important demographic and selected economic characteristics in Limpopo province...	62
Table 3.5 Statistical information on employment and unemployment levels in Sekhukhune District – Community survey, 2007.....	63
Table 3.6 Statistical information on employment and unemployment levels in Capricorn District - Community survey (2007)	64
Table 3.7 Education profile of Sekhukhune District Municipality- Community survey (2007)....	67
Table 3.8 Education profile of Capricorn District Municipality- Community survey (2007).....	68
Table 4.1 Summary characteristics of sample in 10 local municipalities.....	82
Table 4.2 Age of farmers.....	84
Table 4.3 Education level of farmers.....	85
Table 4.4 Farmers response to climate variability and change impact on their livelihoods.....	95
Table 4.5 Farmers response to climate variability and change: Impact on Agricultural production	96
Table 4.6 Farmers response to climate variability and change: Impact on Food security	96
Table 4.7 Univariate analysis of potential determinants of agricultural production	97
Table 4.8 Univariate analysis of potential determinants of unemployment	100
Table 4.9 Univariate analysis of potential determinants of food scarcity	102
Table 4.10 Univariate analysis of potential determinants of food prices.....	103
Table 5.1 Drought stricken districts in Limpopo province.....	108
Table 6.1 Perceived farmers adaptation strategies in Limpopo province (% of respondents)....	120
Table 6.2 A comprehensive list of barriers identified in Capricorn and Sekhukhune districts....	122

LIST OF ABBREVIATIONS AND ACRONYMS

ABARE:	Australian Bureau of Agricultural and Resource Economics
ADB:	Asian Development Bank
ADB:	African Development Bank
ARC:	Australian Research Council
AusAID:	Australian Agency for International Development
BFAP:	Bureau for Food and Agricultural Policy
CAADP:	Comprehensive African Agriculture Development Programme
CAMCO:	Certified Association Management Company
CCSP:	Climate Change Science Program
CCSR:	Center for Climate Change Research
CDM:	Capricorn District Municipality
CEP:	Communicating Environment Programme
CGIAR:	Consultative Group on International Agricultural Research
CIFOR:	Center for International Forestry Research
CME:	Chicago Mercantile Exchange
COAG:	Council of Australian Governments
COPA:	Committee of Professional Agricultural Organisations
CSAG:	Climate Systems Analysis Group
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
CSIRO-BOM:	Common Scientific and Industrial Research Organisation and Bureau of Meteorology
DAFF:	Department of Agriculture, Forestry and Fisheries
DBSA:	Development Bank of Southern Africa
DEA:	Department of environmental affairs
DEAT:	Department of Environmental Affairs and Tourism
DFID:	Department of International Development
DoE:	Department of Education
DWAF:	Department of Water Affairs and Forestry
EC:	European Commission
EEA:	European Environmental Agency
ECLAC:	Economic Commission for Latin America and Caribbean
EU:	European Union

FAO:	Food and Agricultural Organisation
FEMA:	Federal Emergency Management Agency
GDP:	Gross Domestic Product
GGP:	Gross Geographic Product
GRSA:	Government Republic of South Africa
GSA:	Grain South Africa
GSDM:	Greater Sekhukhune District Municipality
IFAD:	International Fund for Agricultural Development
IFOAM:	International Federation of Organic Agriculture Movements
IFPRI:	International Food Policy Research Institute
ILO:	International Labor Organisation
IPCC:	Intergovernmental Panel on Climate Change
ISSET:	International Symposium on Emerging Technologies
IUCN:	International Union for Conservation of Nature
IUFRO:	International Union of Forest Research Organisation
LDA:	Limpopo Department of Agriculture
LEDET:	Limpopo Department of Economic Development, Environmental and Tourism
LEGDP:	Limpopo Employment Growth and Development Plan
LIMDEV:	Limpopo Economic Development Enterprise
MERK:	Ministry of Environment, Republic of Korea
MG:	Mail and Guardian
MIG:	Montreal Implementation Group
NAFU:	National African Farmers Union
NAST:	National Academy of Science and Technology
NDA:	National Development Agency
NGO:	Non Governmental Organisation
NSWSG:	New South Wales State Government
OECD:	Organisation for Economic Co-Operation and Development
PACJA:	Pan African Climate Justice Alliance
PMSEIC:	Prime Minister Science, Engineering and Innovation Council
RDP:	Reconstruction and Development Programme
RSA:	Republic of South Africa
SADC:	Southern African Development Countries

SAIRR:	South African Institute of Race Relations
SAWC:	Southern Africa Wildlife College
SAWS:	South African Weather Service
SAYB:	South Africa Year Book
StatsSA:	Statistics South Africa
TGA:	Tomato Growers Association
TIL:	Trade Investment Limpopo
UNDP:	United Nations Development Program
UNECA:	United Nations Environmental Climate Adaptation
UNESCAP:	United Nations Economic and Social Commission for Asia and Pacific
UNISDR:	United Nations International Strategy for Disaster Reduction
UNFCCC:	United Nations Framework Convention on Climate Change
USEPA:	United States Environmental Protection Agency
VCC:	Victorian Coastal Council
WAPC:	Western Australia Planning Commission
WMO:	Weather Meteorological Organisation
WHO:	World Health Organisation
WSDP:	Water Services Development Plan

CHAPTER 1

1.1 Introduction

Climate change directly affects agricultural production, as the agricultural sector is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impact of global climate change (Parry *et al.*, 1999). According to UNEP (2008) “humanity is living beyond its environmental means and running up ecological debts that future generations will be unable to repay as a result of global climate change”. Global climate change results in reduced food production, leading to higher food prices and making food less affordable for poor people. According to IPCC (2011), the global community is facing the impact of climate change both now and the future. Additionally, it is widely recognised that the severest impacts are more, likely to be experienced in developing countries (largely due to low capacity of populations, to adapt coupled with fragile infrastructure). Agricultural production remains the main source of livelihood for the majority of rural communities in Africa, for example providing employment to more than 60 percent of the population and contributing about 30 percent of gross domestic product (Nhemachena and Hassan, 2007).

Southern Africa is expected to experience increases in temperature and declining rainfall patterns as well as increased frequency of extreme climate events (such as droughts and floods) as a results of climate change (Nhemachena, 2008). The key issues affecting Southern Africa with respect to climate change are its effects on livelihoods, the ability to reduce poverty and provide food and water security (IUCN, 2002). This effect of climate change on agricultural production includes (a) Reduction in crop yields (b) Increased incidence of pest attacks (c) Limiting of water availability (d) Abnormal droughts periods (e) Reduction in soil fertility (f) Low livestock productivity and (g) High production costs. It is important to also note that it is not only climate change which is affecting the Southern Africa but climate variability also poses a serious threat to the various sectors such as water, health etc across the regions. However, climate variability and change is an additional stress to existing challenges such as High unemployment, Poverty, HIV/AIDS etc.

According to Scholes *et al.*, (1999) South Africa, as part of Southern Africa is predicted to be vulnerable to climate change due to the combined effects of the following:

- South Africa is a semi-arid country where the bulk of farming is practiced on marginal land.
- Frequent occurrence of droughts.
- Scarcity of water, which is exacerbated by a high temporal and spatial variability of rainfall.

The importance of agriculture in South Africa may be gauged by the fact that while the country only covers 4 percent of the African continent, it produces over 30 percent of the continent's maize, nearly 30 percent of sugarcane, around 20 percent of its mutton and beef and 30 percent of wheat, as well as being one of the world's seven leading net exporters of food products (Terblanche, 1996). Again Teri (2006) further emphasise that high level of food and water stress will worsen the vulnerability of the poor in three main ways : (a) Increased insecurity of livelihoods (due to depleted access to natural resources that include water as well as other social , financial and physical assets) (b) Increased health risks (vulnerability of food and water resources have serious implications for health (c) Floods are associated with spread of diseases such as malaria) and (d) Constrained economic opportunities like short and long-term impacts of droughts (Teri , 2006).

It was also suggested by World Bank (2010) that South Africa has been getting hotter over the past four decades. There has also been an increase in the number of warmer days and a decrease in the number of cooler days. Moreover, the country average rainfall, estimated at 450 mm per year is well below the average of 860 mm, while evaporation is comparatively high (World Bank, 2010). In addition, surface and underground water resources are limited. Agriculture is expected to be the most affected by these changes because it is highly dependent on climate variables such as temperature, humidity and precipitation (IPCC, 2011). Climate change, by adversely affecting food and water resources, will threatens progress and efforts made in accelerating agricultural crop production in South Africa.

1.2 Research Problem

The African continent has been highlighted as particularly vulnerable in the future to climate change, primarily due to its low adaptive capacity, limited financial reforms and its sensitivity to many of the projected changes (IPCC, 2007; Callaway 2004). Additionally, climate change is taking place in the context of other developmental stresses, notably poverty, fluctuating oil prices and food insecurity (FAO, 2006), as well as in combination with environmental change, drought and land degradation (Thomas *et al.*, 2008). It is thus essential to develop and implement effective adaptation measures so that climate – related risks and opportunities might support development objectives within local and policy decision making processes (Adger *et al.*, 2003; IPCC, 2007).

Climate change is also emerging as one of the main challenges of humankind will have to face for many years to come. It could become a major threat to world food security, as it has a strong impact on food production, access and distribution. Furthermore, given an estimate of 3 million farmers who produce food primarily to meet their family needs, rural poverty in South Africa could be worsening with climate change (StatsSA, 2007). Indeed, due to their low income, lower technological and capital stocks, households are predicted to have limited options to adapt to climate change (Mendelssohn *et al.*, 2000).

It was also discussed at the fifth Alexander von Humboldt International Conference in Cape Town in 2009 that maize yields in South Africa's will decrease by approximately nine percent between now and 2045 if climate change impacts are not addressed. This decline will pose a major problem, as maize is the region's main staple food. However if adaptation strategies are provided and this will make significant contribution in improving agricultural crop productivity and food security as well as help to reduce poverty in South Africa.

1.3 Hypothesis

1. In Limpopo province, most areas are hot and some are also dry, increases in warming and declining precipitation are expected to have negative impacts on agricultural crop production.

2. In Limpopo province, there are districts that are experiencing dry and average wet conditions, this will result in increased seasonal rainfall and increased agricultural crop production.
3. Improved access of resources such as credit, extension, information etc enhances farm level use of adaptation measures and this could improve the farming activities in the province.

1.4 Aims and Objectives

1.4.1 Aim

The primary aim of this study is to identify the impacts and adaptation options of climate variability and change on agricultural production in Limpopo province.

1.4.2 Objectives

- i. To understand the impacts of climate variability and change on agricultural production in Limpopo province.
- ii. To assess the impacts of climate variability and change on agricultural production in Limpopo province.
- iii. To identify adaptation measures that could reduce the impacts of climate variability and change on agricultural production in Limpopo province.

1.5 Significance of the study

The impact of climate variability and change has a negative impact on agricultural crop yields and it is important to understand and assess them in order to provide best adaptation strategies. Climate variability and change adaptation strategies are the effective way to promote agricultural production during periods of unexpected weather. Based on the physical risks that climate change poses to especially developing countries including South Africa, adaptation measures with regard to food, water, livelihood and energy security is paramount in social adaptation responses to climate change (CSAG, 2008). Physical impacts such as extreme weather events, for example droughts and desertification are

expected in the southern and central part of South Africa and then also in contrast to this, floods and prolonged precipitation are forecast as some of the effects of climate change on the physical environment (CSAG, 2008). According to IPCC (2007) there are serious concern regarding the vulnerability of developing countries in the plight of climate change. Providing the households with necessary adaptation strategies increases their productivity and helps them to adapt to the adverse consequences of changing climatic conditions.

1.6. Research methodology

1.6.1 Study sites are (a) Greater Sekhukhune and Capricorn districts in Limpopo province

The study areas are in Limpopo province, which is in the northern part of South Africa. It is the gateway to the rest of Africa, with its shared borders making it favourably situated for economic cooperation with other parts of Southern Africa (StatsSA, 2011). Two districts were selected as the study areas, namely Greater Sekhukhune and Capricorn (Figure 1.1). This was based on different agricultural setups and the different agro - climatic conditions.

The Greater Sekhukhune district (Figure 1.1) is one of the five districts in Limpopo province. It is a cross boundary district between the Limpopo and Mpumalanga provinces. The district has five local municipalities, namely *Fetakgomo*, *Makhudu Thamaga*, *Ephraim Mogale*, *Elias Motsoaledi* and *Greater Tubatse* (StatsSA, 2011). The Greater Sekhukhune district is blessed with climate which is ideals for agricultural activities. Agriculture is one of the core businesses in the district and generates lot of the area's annual income (StatsSA, 2007).

The Capricorn district (Figure 1.1) is the third largest district economy in Limpopo Province (StatsSA, 2011) after Waterberg and Mopani Districts. It is made up of five local municipalities, namely Aganang, Blouberg, Lepelle – Nkumpi, Molemole and Polokwane. According to StatsSA (2007) agriculture accounts for 2.8 percent of the district economy and contributes R690 million per annum. Capricorn district has a climate ideal for agricultural activities but lately is experiencing environmental problems (LEDET, 2008). It

was also highlighted by Oni *et al.*, (2003) that agricultural production in Capricorn district is at risk due to drought and other natural disasters.



Figure 1.1: Geographic location of the Greater Sekhukhune and Capricorn Districts in Limpopo province
Source: StatsSA (2006)

1.6.2 Data collection, sampling and analysis

This research has used both quantitative and qualitative design. A temperature and rainfall parameters for the past 30 years for two selected districts were obtained from the South African Weather Services. Data on crops yield per tons, production and percent area planted for the past 30 – 50 years was obtained from the National Department of Agriculture. Permission was asked from the two district offices to conduct research in their different municipalities. The survey targeted three hundred farmers in those districts. The two districts were asked to provide the list of farmers in their municipalities.

Purposeful sampling technique was used to select three hundred farmers to be interviewed. The questionnaire included matters relating to climate change and agricultural production were used in the interviews. Before the interviews start a village meeting was conducted

with all community representatives present: chiefs, indunas, local councillors and NGO's. The nature of the research and the contents of the questionnaire were explained to them. Focus group discussion was conducted after face to face interviews with farmers. Data was captured and analysed using software package for social science (SPSS). Descriptive analysis was used to describe data and Univariate analysis was conducted to demonstrate the relationship and association of variables.

1.7 Summary

- 1) It is assumed that majority of farmers in both Capricorn and Sekhukhune districts are using different coping and adaptation strategies in order to increase their crop yields, for example crop diversification, planting early matured maize varieties etc.
- 2) In the chapter several literature shows that climate change adaptation strategies vary from area to area due to agro ecological zones and the harshness of the effects of climate variability and change. The next chapter describes and focuses on the theoretical and empirical studies relating to climate change adaptation. The next chapter will also outlined the threats, impacts that climate change poses across key strategic climate – sensitive sectors across the globe.

CHAPTER 2

Theoretical and empirical studies relating to climate change adaptation

2.1 Introduction

According to IPCC (2007) the scientific community widely agreed that climate change is already a reality. Over the past century, surface temperatures have risen, and associated impacts on physical and biological systems are increasingly being observed. 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. Climate change is also likely to increase the frequency and magnitude of extreme weather events such as droughts, floods and storms. While there is uncertainty in the projections with regard to the exact magnitude, rate and regional patterns of climate change, its consequences will change the fates of generations to come.

In addition, 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 greenhouse gases, 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 greenhouse gas emissions, primarily as a result of the over use of fertilizers, land clearance, soil degradation, and intensive animal farming. The total global contribution of agriculture to climate change, including deforestation for farmland and other land use changes, is estimated to be equivalent to between 8.5 -16.5 billion tonnes of carbon dioxide or between 17- 32 percent of all human-induced greenhouse gas emissions (Smith, 2008).

While agriculture is one of the most important sources of emissions of greenhouse gases, the sector is increasingly being recognized for its potential to be part of the solution (IPCC, 2007). It should however be emphasized that rather than pursuing a one-size-fits-all

decrease in agricultural emissions, efforts should focus on policies that deliver a win-win outcomes to enhance agricultural productivity, promote food security and sustainable livelihood, and that contribute to climate change adaptation, which appears to be the key tactic to saving billions of money and saving lives.

Climate changes are serious issues across all sectors of the economy. Key aspects associated with climate change includes adaptation and the mitigation of climate variability and change. Climate change is not just an environmental-climatic dimension but also a regulatory-market economy dimension. The latter includes government measures that are supposed to tackle climate change and its negative consequences. This dimension will affect most sectors such as water resources, human health, coastal zones, infrastructure, and ecosystems. Climate change will also challenge policy makers to simultaneously meet the needs of growing communities, sensitive ecosystems, farmers, ranchers, energy producers and manufacturers (IPCC, 2007).

2.2 Impact of climate change in various sectors across the globe

2.2.1. *Water resource based on international perspective*

In Asia, for example, it is expected that one billion people could face water shortage leading to drought and land degradation by the 2050s (Christensen *et al.*, 2007, Cruz *et al.*, 2007). There will also be an increase in water stress to over a hundred million people due to decrease of freshwater availability in Central, South, East and Southeast Asia (Cruz *et al.*, 2007). As glaciers disappears in some parts of Asia there will be floods and slope destabilisation. According to Cruz *et al.*, (2007) the capacity to adapt in Asia varies between countries and it depends on social structure, culture, economic capacity, geography and level of environmental degradation. But they stressed the fact that adaptation measures are increasing in some parts of Asia, for instance, the success of early warning systems in Bangladesh and Philippines offers good hope with lack of adaptation in some countries (a) Due to poor resources (b) Weak institutions (c) Inequality in income and (d) Limited technology.

According to UNEP (2007) South American countries like Bolivia, Chile, Ecuador and Peru which depend on glacial seasonal discharge will face a serious water challenge as Andean glaciers start to disappear. It was further stressed by Magrin *et al.*, 2007 that about 7 – 77 million will experience water stress by 2020. There will also be uncertain rainfall changes over northern South America, including the Amazon forest. But according to World Bank (2007) water management project in the Andean region which is to be established is expected to offer better adaptation options against climate change through: an analysis of current glacier hydrology, including an update of previous glacier inventories, glacier variations, and records of glacier melt hazards and disasters; estimation of the availability of water resources due to glacier melt at the national level up to 2050; and an evaluation of adaptation strategies in the management of hydro resources in basins with a glacier under climate change conditions.

Water resource will be affected by climate change across North America but the nature of vulnerabilities will vary from region to region (NAST, 2001, Lemmen and Warren 2004). In certain regions including the Colorado River, Columbia River and Ogallala Aquifer, surface and/or groundwater resources are intensively used for often competing (a) Agricultural (b) Municipal(c) Industrial and ecological needs (d) Increasing potential vulnerability to future changes in timing and availability of water. But according to Lemmen and Warren (2004) North America has a well-developed economy with extensive infrastructure, mature institutions to adapt in the water sector. The region has also invested much in buildings, infrastructure, water and flood management systems designed to perform well under unacceptable weather conditions (Bruce, 1999).

There is an ongoing climatic change in Europe 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 the increases in temperature, sea level and precipitation variability. New approaches have been developed across Europe to deal with problem. According to Wostl and Moltgen (2006) water management is a good strategy to adapt against climate change. They further emphasise 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. There are also new approaches on adaptive water management under NeWater project in Europe (Wostl and Moltgen 2006).

This new approach focuses on the transition from current regimes of water management in a river basin to more integrated, adaptive approaches. According to Kundzewicz *et al.*, (2006) Europe in general has a high adaptation potential in socio-economic terms due to strong economic conditions, high gross domestic product, stable growth, stable, well-trained population with capacity to migrate within the super-national organism of the European Union, and well developed political, institutional, and technological support systems

According to Hennessy *et al.*, (2007) the water sector in Australia, for example, is vulnerable to climate change, with potential negative impact on freshwater, ground water and water quality. They further emphasise that this vulnerability requires high level of adaptive responses. However, Australia is developing climate adaptation protocols and risk management strategies specifically for the water sector. According to CSIRO (2009) Australia has embarked on the following adaptation measures:

- (a) To develop approaches to managing water resources that take into account climate change projections,
- (b) To evaluate the costs and benefits of increasing on-farm and systems efficiencies via better use of technology,
- (c) Co-ordination of delivery mechanisms,
- (d) Evaporation control,
- (e) Retrofitting leaky systems,
- (f) The provision of probabilistic seasonal forecasts,
- (g) Improved scheduling and better understanding of what is needed to implement such measures in a range of different circumstances;
- (h) To incorporate climate change considerations more effectively into integrated catchment management,
- (i) To addressing the relationships between water quality,
- (j) Surface and groundwater extraction,
- (k) Waterway management and land-use,
- (l) To evaluate whether there are clear thresholds in irrigated agriculture,
- (m) The implications for water resource management under climate change
- (n) To develop a framework for water resource management that takes account of on-going conditions, where business as usual,

(o) Watching brief,

(p) Near critical and emergency management are all codified stages that contain strategic considerations relevant to planning horizons under climate change.

2.2.2. Water Resource based on continental perspective

According to Nyong and Kandil (2009) water is a key component of Africa's natural resources endowments and is fundamental to economic development. They point the fact 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 worsening by climate change which has made water increasingly scarce in Africa. Adaptation in the water sector is also difficult due, (a) To weak institutions (b) Low skills base (c) Conflicts (d) Lack of infrastructure and lack of financial resources. This has resulted in African Union, African Development Bank and United Nations Economic Commission for Africa to join forces in addressing climate change adaptation in Africa. They seek to achieve the following: (a) To strengthen institutions at all levels to develop capacities to address the challenges of climate change; (b) Support the development and/or rehabilitation of data collection and monitoring systems to provide easily accessible climate and water data and the ClimDev Fund will help leverage substantial financial resources to support climate change adaptation in the water sector. The National Aeronautics and Space Administration (NASA) is also closely associating with existing institutions in the Nile basin (Ethiopia, Eritrea, Uganda, Rwanda, Burundi, Congo, Tanzania, Kenya, Sudan and Egypt) to develop satellite-based water management and forecasting techniques, improving hydrological data for cooperative water management (IPCC,2007).

Lack of water is a major constraint on development in Africa. Although Africa contains rich water resources with large rivers and lakes, it is the second driest continent in the world, after Australia. 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).

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 40-150 percent for 2020 and 150-1200 percent for 2050 and by the year 2020, all river basins will be vulnerable and some parts of Africa will face acute water shortage (Schulze, 2000).

2.2.3. *Water Resource based on regional perspective*

Southern Africa is particularly vulnerable to extreme variability, given its high dependence on rain-fed agriculture and water resources for livelihoods; limited knowledge on climate change; limited resources for adaptation; and lack of institutions and capacity to regulate river and stream flow (Schulze *et al.*, 2005). According to Schulze *et al.*, (2005) Southern Africa water is largely driven by climate and rainfall and river flows display high levels of variability with important consequences for the management of water resources systems. This was further emphasise by Nyong and Kandil (2009) when they said 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. According to Nyong and Kandil (2009) the adaptation measures that is encouraged in Southern Africa includes the following: (a) Establishment of integrated management in water resources (b) Sustained infrastructural development (c) Strong institutions for good water governance (d) Innovative financing mechanisms (e) Effective Partnership with developmental partners and strong political commitment.

The majority of the population in the region (over 70 percent) depends on agriculture; mainly rain-fed agriculture. Therefore, understanding the impacts of climate change on water resources is of paramount importance in the region. According to Manase (2009) growing water scarcity, an increase in the population, the degradation of shared freshwater ecosystems and competing demands for shrinking natural resources have the potential for creating bilateral and multilateral conflicts in the Southern African Development Community (SADC) region. The researcher further elaborate that although uncertainties still pertain to the exact future impact of climate change on water resources, SADC countries should start integrating climate change in water sector and national strategies. Climate change is also expected to alter the present hydrological resources in Southern

Africa and add pressure on the adaptability of future water resources (Schulze and Horan, 2010).

Since much of the Southern African Development Community (SADC) region experiences water scarcity, poor distribution of water resources and pollution, coupled with frequent droughts and floods, have led to direct hardship for many people, particularly the poor, since it has affected health and food security (SADC, 2002). According 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 runoff overall will exacerbate current water stress, reduce the quality and quantity of water available for domestic and industrial use and limit hydropower production.

2.2.4. Water Resource based on national and provincial perspectives

According to Schulze (2000) South Africa's water sector faces two major challenges: (a) Limited water resources; (b) The need to ensure that the benefits of those resources are distributed equitably. The adverse impacts 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 present population growth trends and water use behaviour indicates that South Africa, as a water scarce country, will exceed the limits of its economically usable, land-based water resources by 2050. According to Ziervogel *et al.*, (2006) South Africa needs to reevaluate water intensive development such as irrigated agriculture and certain types of mining, which is likely to increase local vulnerability as it increases exposure to water stress. DWAF (2008) stated that priority needs to be given to developing robust strategies to ensure that demand matches supply, even where water availability is reduced. In addition, new water systems need to be designed and managed in a way that will accommodate future higher demands, increases in temperature and rainfall variability. Consequently, institutions need to encourage technical appropriate technology that range from large-scale water provision for economic growth through to micro-level processes to provide water to rural development (DWAF, 2008).

Water institutions will have to develop greater capacity to manage risk, to manage uncertain conditions, and therefore to adapt more readily to new and different conditions.

As a result, local municipalities will need to manage increased run-off and stormwater drainage, and strengthen their disaster management systems (DWAF, 2008).

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. According to DEA (2010) the present population growth trends and water use behaviour indicates that South Africa, as a water scarce country, will exceed the limits of its economically usable, land-based water resources by 2050. The Department further emphasize that South Africa is facing two major challenges: (a) Limited resources and the need to ensure that the benefits of those resources are distributed equitably (b) But it was also acknowledged that the adverse impacts of climate change will worsen the existing problem of systemic water shortages and will bring forward the limits to water resources.

According to both DEA (2010) and DWAF (2008) following challenges are posed by climate change in South Africa:

- Increased variability of storm-flow and dry spells - By ~2050 the frequency of storm-flow events and dry spells is projected to increase over much of the country.
- Increased cost - The cost of providing water will rise. It is estimated that just a 10 percent decline in run-off could double the cost of new water schemes, raising the cost to the fiscus and users of new infrastructure developments.
- Rising temperatures - Climate change will bring higher average temperatures. This is projected to lead to more erratic weather, more flooding and greater rainfall variability.

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 west (DEA, 2010). In addition, groundwater recharge could reduce significantly in the semi-arid parts of the interior

and west. Agriculture which is the largest consumer of water (for irrigation), and is vulnerable to changes in water availability, increased water pollution (particularly from toxic algal or bacterial blooms) and soil erosion linked to more intense rainfall events will be hit the hardest (DEA, 2010). The rural and peri-urban poor in provinces like Limpopo are at most risk, as they rely on untreated water derived directly from rivers, wells and wetlands.

Water resource is already under pressure in Limpopo province, and climate change will lead to a decline in the availability of surface water resources. This will happen at the same time as socio-economic development will increase the demand for water. According to Sonjica (2009) Limpopo province is one of the most poorly developed province when it comes to water resource and water provision backlog in Limpopo now stood at 55 000 households, and billions of rands were being invested to try and solve the problem. Climate change is also making things worse because of droughts in the province. Groundwater in Limpopo province has been severely over exploited, resulting in water insecurity for almost half the population who are depending on it in the province. There is currently a critical demand for water in Limpopo as a result of drought, which demands a significant response and level of intervention.

In the response to challenges faced by water sector as results of climate change, the South African government is planning to do the following across its nine provinces: (1) To develop and maintain good water management systems (2) Water related infrastructure and institutions from village through to national level (3) To accelerate the development and/or capacity of effective and accountable catchment management agencies (4) To invest in monitoring capabilities across a range of disciplines in order to spot trends and understand them as well as track the efficacy of adaptive strategies (5) To optimise the re-use of wastewater (6) To increase investments wastewater treatment capacity to meet stipulated norms and standards for waste discharge (7) Develop and implement an household rainwater harvesting incentive programme (8) To develop early warning system and (9) to develop and rollout more effective support mechanisms to ensure that safe drinking water is available to all with a priority of ensuring that affordable access for all is safeguarded (DEA, 2010).

2.2.5 Ecosystem and biodiversity based on international perspective

According to IPCC (2007) projected climate changes in North America will continue to put pressure on natural ecosystems (e.g. rangelands, wetlands, and coastal ecosystems). Projected changes in climate should be seen as an additional factor that can influence the health and existence of these ecosystems. In some cases, changes in climate will provide adaptive opportunities or could alleviate the pressure of multiple stresses; in other cases, climate change could hasten or broaden negative impacts, leading to reduced function or elimination of ecosystems. According USEPA (2010) North America is adapting fairly well because of the following measures being used: (a) It is protecting and enhancing migration corridors to allow species to migrate as the climate changes (b) It has identified management practices that will ensure the successful attainment of conservation and management goals and it is promoting management practices that confer resilience to the ecosystem.

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; loss of ecosystem services. It was further stressed by COAG (2007) that the following adaptation be used to adapt against changing weather patterns: (a) Protect and replant wildlife corridors to facilitate migration of species under future warming (b) Revegetate and manage developed land to maximise the north-south connectivity between national parks and other reserves (c) Consider translocation of iconic species (this is a measure of 'last resort' due to cost) (d) Reduce local stresses (water quality, fishing pressure) on coral reef systems to encourage recovery and reduce mortality and assist dispersal of species that become 'stranded' as their bioclimatic zone moves (IPCC, 2007).

According to FAO (2003) climate change will have a profound effect on the future distribution, productivity and health of forests throughout Asia, for example northeast China may become deprived of conifer forest. Grassland productivity is expected to decline by as much as 40 – 90 per cent for an increase in temperature of 2 – 3° C combined with reduced precipitation, in the semi-arid and arid regions of Asia. This pressure on Asia ecosystem will also lead to an increased risk of extinction for many

species due to the synergistic effects of climate change and habitat fragmentation. 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 Rowell and Moore (2000) 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. This can results in forests being replaced by ecosystems that have more resistance to multiple stresses caused by temperate increase, fires and droughts. According to Colls *et al.*, (2009), World Bank (2009) there is an approach used in South America called ecosystem – based approach (EbA) whose aim takes into account the role of ecosystem services in reducing the vulnerability of society to climate change in a multisectoral and multilevel way. This ecosystem – based approach can directly benefit climate change adaptation through increasing and maintaining carbon stocks.

Climate change in Europe has the potential to affect key aspects of the ecosystems ranging from physical parameters, such as sea temperature or ocean circulation, to biodiversity and ecological processes (EEA, 2005). According to EEA (2005) the impacts include ecosystem undergoing structural changes due to climate change resulting in the loss of key species, large concentrations of planktonic species replacing other species and a spread of invasive species. But Europe like other regions has adopted the ecosystem approach strategy as an adaptation measure. This approach will address the crucial links between climate change, biodiversity and sustainable resource management and thus provide multiple benefits. Implementing such approaches can contribute to both the reduction of greenhouse gas emissions and the enhancement of sinks as well as improve biodiversity conservation, livelihood opportunities and health and recreational benefits (EU, 2009).

2.2.6 Ecosystem and biodiversity based on continental perspective

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. According to Boko *et al.*, (2007) up to 50 per cent of Africa's total biodiversity is at risk due to changing weather patterns. They further 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. In order to adapt Africa should build an understanding of ecosystems based adaptation concepts, review capacity building and educational efforts around ecosystems based adaptation, provide feedback on current research into ecosystems based adaptation, promote discussion and planning of ecosystems.

2.2.7 Ecosystem and biodiversity based on regional perspective

Ecosystem is an important resource for Southern African communities (IPCC, 2001). It is also predicted that there will be major changes in ecosystems with mainly negative consequences for biodiversity and ecosystem services (water and food). The acidification of oceans will have negative impacts on marines and the species that depends on them. Climate change will also results in a loss of species and extinction of many plants and animals. According to Scholes (2006) ecosystems changes are already being detected in Southern Africa, at a faster rate than anticipated as a result of climate change. As a results Scholes (2006) outlined the following adaptation measures to use: (a) To develop and test methods to project the dynamic response of biodiversity to climatic change (b) To develop conservation planning tools for the prioritization of conservation planning in an environment which is non-static as a result of climate and land use change (c) To evaluate in terms of economic costs and effectiveness adaptation options for biodiversity conservation when faced with climate change and a fragmented landscape (d) To advance the field of dynamic biodiversity and ecosystem conservation and (e) To develop capacity in both the research and management communities to address climate change issues in a proactive and effective way.

2.2.8 Ecosystem, Forestry and biodiversity based on national and provincial perspectives

According to DEA (2010) there is a range of biodiversity impacts predicted in South Africa. This includes major range shifts for individual species and ecosystems, as well as changes in community structure, such as potential invasion of grasslands by woody plants because of increasing levels of carbon dioxide (DEA, 2010). Overall, there is likely to be shrinkage and shifting of optimal areas for major biomes, and range shifts of many species, particularly endemics, as well as an increase in extinctions (DEA, 2010).

According to DEA (2010) the formal forestry sector faces a wide range of potentially plausible outcomes that are very sensitive to projected rainfall change. The South African forestry industry is highly sensitive to climate change. Currently, only 1.5 percent of the country is suitable for tree crops and the forestry sector is affected by factors such as land availability, water demand, and socio-economic conditions. Drought during 1991/92 caused the loss of approximately R450 million to the industry. With expected temperature increases by ~2050 of 2°C and a reduction in rainfall of 10 percent, most forestry species show reduced viable production area of between 40 percent and 100 percent. It was further emphasized by DEA (2010) that based on the reduction in highly suitable area for forests by 2050, forestry output could be decreased by as much as 43 percent, implying a loss of value in the order of R724 million per annum. There is also frequency and intensity of fire which is likely to increase due to an increase in temperature and dry spells caused by more erratic rainfall (DEA, 2010). This will ultimately lead to negative impact on plantation forestry.

The forestry industry could probably tolerate a small increase in temperature, but a decrease in rainfall would reduce the area which can support plantations, and the growth rate of the trees. In Limpopo province for example, one of the area affected by climate change is the Mapungubwe heritage site, which is renowned for its golden rhino artefact that has become the icon of a society which settled close to the Limpopo River for some 400 years between about 900 and 1300 AD (LDA, 2010). It is also known for its giant baobab trees, riverine forests and associated flood plains provide an intriguing mix of habitat for a tremendous diversity of creatures. But according to LDA (2010) the impact of climate change has resulted in drought accounting for 76 percent of trees lost, and the 2000

flood for an additional 21 percent. Creepers were implicated in the drought-related death of nearly half of the trees which succumbed to drought, but interestingly their effect was felt mostly by species with microphyllous (small) leaves, such as *Acacia xanthophloea*, rather than broad-leaved species.

To address this challenges the South African government has outlined the following actions across all three spheres of government: (a) To prioritise support for monitoring efforts and experimental studies at national and sub-national scale aimed at evaluating future risks to biodiversity (b) Improving model projections of impacts, and informing the design and assessment of adaptation responses (c) To encourage and facilitate the building of partnerships to enable effective management of areas not under formal protection and investment in the expansion of key protected areas in line with the most robust knowledge of climate change impacts (d) To ensure that protected area planning and expansion strategies benefit from an eco-system approach and focus to ensure that threatened biomes, landscapes and species are given special protection and that conditions are established that will minimise the risks of species extinction(e) To ensure that a comprehensive biodiversity monitoring system is established that can provide timely information on specific risks (f) To expand existing programmes to combat the spread of alien and invasive species and the destruction of sensitive ecosystems and (g) To promote efforts to conserve, rehabilitate and/or restore natural systems that reduce and/or improve resilience to climate change impacts (DEA, 2010: 90).

2.2.9 Infrastructure based on continental perspective

According to IPCC (2007) Africa's infrastructure deficit is and most existing infrastructure has been built with low energy efficiency and based on historical climate information. It is estimated by World Bank that \$ 93 billion is needed to improve Africa's infrastructure; nearly half of it on power supply and roads caused by floods. This change in climate in Africa will stress current infrastructure, exacerbating existing weaknesses and forcing major programmes of renewal and replacement, well-supported with finance and technology and implemented by skilled workforces.

This climate change impact on infrastructure is a major challenge to Africa's economic development and constitutes a major impediment to the achievement of the Millennium Development Goals (MDGs) and other vital objectives, such as revitalizing agriculture. The impacts are enormous. From rural roads, railways and harbors to irrigation systems, telecommunications, clean water, sanitation, energy and such basic social infrastructure as health, education, banking and commercial services. This is particularly true in rural areas, where the majority of the continent's 920 million people live (IPCC, 2007). The burden also falls most heavily on women, who often must spend hours collecting wood for cooking and heating in the absence of electricity. Rural women walk an average of 6 kilometers daily to rivers and springs for want of piped water and wells (Maponya, 2008).

According to assessments of Africa's infrastructure done in 2006 by the African Development Bank (ADB, 2006) less than a third of sub-Saharan Africans have electricity, only 56 per cent drink clean water, barely a third of rural Africans live near a road, just 4 per cent of Africa's farmland is irrigated, over 60 per cent of the population lacks basic sanitation facilities and less than a quarter of paved roads per kilometer than other developing regions.

2.2.10 Infrastructure based on regional perspective

Climate change can directly affect trade-related infrastructure, or trading routes in Southern Africa. Rising sea levels may endanger coastal infrastructure that supports trade, such as ports. In addition, extreme weather events can be expected to disrupt markets and infrastructure (Sachs *et al.*, 2004). One of the predicted effects - increased flooding - will affect infrastructure as well as transport routes, as was the case during the 2000/2001 flooding in Mozambique where roads and railway lines were washed away. As noted by Sachs *et al.*, (2004), before high-intensity modern trade can get started, Southern Africa needs an extensive road system both from the coast to the interior and within the interior, where the highest population concentrations are found. These roads, however, are very expensive to build and maintain. Destruction of the existing roads infrastructure due to floods will severely affect trade in Southern Africa (Van Langenhove, 2009). It was also estimated by World Bank that flooding in 2009 has caused a damage of \$ 620 million in some parts of Southern Africa.

2.2.11 Infrastructure based on national and provincial perspectives

According to Shiceka (2011) the government has recommended that a national state of disaster be declared covering seven provinces and 28 municipalities following the recent floods in South Africa. The provinces are Gauteng, Free State, KwaZulu-Natal, Mpumalanga, North West, Northern Cape and Limpopo. In some provinces, the floods have made it impossible for children to go to school, while in others; infrastructure such as bridges has been washed away. It was also confirmed by Shiceka (2011) that 40 people had lost their lives in the floods while more than 6 000 people had been displaced. This condition was further stressed by Schulze (2011) that weak infrastructure management and poor planning will exacerbate the serious effects of climate change on South Africa's water supply and thus affecting agricultural production since most water is used for irrigation in South Africa.

Schulze (2011) further emphasised that floods on the Vaal river system, described as a once-in-15-years event, had devastating consequences. The floods have highlighted South Africa's vulnerability to climate change, which is expected to change rainfall patterns. According to Schulze (2011) temperature changes seem to be affecting the aging of bitumen on most roads in the country. This subsequently causes road surface to crack, with a consequent loss of waterproofing of the surface seal (Schulze, 2011). The result is that surface water can enter the pavement causing potholing and fairly rapid loss of surface condition.

According to Makhura and Wasike (2003) inadequate infrastructure is a major development challenges in Limpopo province. The Limpopo province is engaged in a major operation to upgrade its transport and general infrastructure to higher modern industrial standards as result of flooding in some parts of the province. There is also a proposed development of additional water resource infrastructure to increase the long term availability of water in parts of Sekhukhune, Capricorn and Mogalakwena parts of Limpopo province that has been affected by droughts. According to Mathale (2011) investment in infrastructure is critical to boost agriculture and rural development against climate change. He further explained that priorities will differ with local, national and regional circumstances, but adequate rural roads and other means of transport, irrigation, water storage, electrification and telecommunications

are all important in response against unreliable weather patterns. Also as a results of this changing weather patterns the Department of Water Affairs has through the bulk Infrastructure grant in the Limpopo province allocated an amount of R228 million in the 2009/10 financial year for funding nine water supply projects. An additional allocation of R28, 66 million in the 2010/11 financial year from the Community Infrastructure Programme to ensure that reticulation takes place in the municipalities.

2.2.12 Coastal zones issues based on international perspective

According to Wassmann *et al.*, (2004) projected sea level rise could flood the residence of millions of people living in the low lying areas of South, Southeast and East Asia such as in Vietnam, Bangladesh, India and China. Coastal inundation is likely to seriously affect the aquaculture industry and infrastructure particularly in heavily-populated mega deltas and stability of wetlands, mangroves, and coral reefs increasingly threatened. It was further emphasised by Cruz *et al.*, (2007) that sea level rise and changes in sea water temperature, salinity, wind speed and direction, strength of upwelling, mixing layer thickness and predator response to climate change have the potential to substantially alter fish breeding habitats and food supply for fish and ultimately the abundance of fish populations in Asian waters with associated effects on coastal economies.

Asia has adopted integrated coastal zone management (ICZM) as a strategy to adapt against climate change. This strategy includes to adaptation to *managed retreat* (move landward to higher ground), to *accommodate* (stay in the same location but make adjustments, e.g., elevate buildings on piles), and to *protect* (employ various hard structures such as seawalls, bulkheads, groins, and breakwaters or use soft measures such as beach nourishment, mangrove replanting, and preservation of coral reefs) (IPCC, 2007).

Countries like (Argentina, Belize, Colombia, Costa Rica, Ecuador, Guyana, Mexico, Panama, El Salvador, Uruguay, Venezuela) and large cities (Buenos Aires, Rio de Janeiro, Recife, etc.) are among the most vulnerable to extreme weather events such as rain, windstorms and hurricanes with their associated storm surges and sea level rise (IPCC, 2007). According to UNEP (2003) sea level rise is likely to have adverse impacts on: buildings and tourism, (e.g. in Mexico, Uruguay); coastal morphology (e.g. in Peru);

mangroves (e.g. in Brazil, Ecuador, Colombia, Venezuela); and availability of drinking water in the Pacific coast of Costa Rica, Ecuador and the River Plate estuary.

According to Magrin *et al.*, (2007) the following response strategies for South America are of vital importance: (a) Information gathering (b) Identification and monitoring of critical exposed elements of coastal ecosystems and human settlements, including the provision of timely climate risk information (c) The identification of critical “hot-spots” or priority areas for the application of adaptation measures geared to monitor and reduce land-based sources of marine (d) Identification of barriers to adaptation in coastal areas of South America (e) To design policy interventions for their effective and efficient removal, for the improved understanding of current and future climate risks and design pilot adaptation measures and capacity development packages for priority sectors and key stakeholders and to contribute to a National Adaptation Strategy for Coastal Areas in South America, with an Action Plan designed to promote adaptation measures for critical exposed systems.

Marine and coastal areas in North America already experience a multitude of climate change related impacts. These changes are beginning to affect ecological and socioeconomic aspects of marine and coastal systems. According to USEPA (2007) sea level rise in rural Washington State is causing land loss and saltwater inundation of aquatic lands, while in the city of Olympia, Washington, sea level rise is projected to cause flooding in the city centre as marine waters travel through existing storm water systems into the interior of the city. This was also agreed by Doyle *et al.*, 2008 that coastal freshwater forests in the Southeast United States of America and in the Gulf of Mexico are undergoing dieback from increasing saltwater intrusion as sea level rises and regional lands subside, in some areas, mangroves are expanding landward.

According USEPA (2010) different adaptation strategies are used across North America, which includes, (a) Developing county-scale maps depicting which areas will require shore protection (e.g. dikes, bulkheads, beach nourishment) and which areas will be allowed to adapt naturally (b) Analyzing the environmental consequences of shore protection (c) Promoting shore protection techniques that do not destroy all habitat (d) Identifying land use measures to ensure that wetlands migrate as sea level rises in some areas (e) Engaging state and local governments in defining responses to sea level rise (f)

Improving early warning systems and flood hazard mapping for storms and Protecting water supplies from contamination by saltwater.

About 80 percent of the Australian population lives in the coastal zone, with significant recent non-metropolitan population growth (Harvey and Caton 2003). About 711 000 addresses (from the National Geo-coded Address File) are within 3 km of the coast and less than 6 m above sea-level, with more than 60 percent located in Queensland and NSW (Chen and McNerney 2006). These are potentially at risk from long term sea-level rise and large storm surges. Some of the adaptation measures being employed by Australia includes: (a) Coastal planning (b) State emergency services (c) Building codes (d) Disaster relief infrastructure and services (e) State inquiry. According CSIRO (2009) the other adaptation measures includes building a stronger base, plus an initial low wall that can be increased in height later. The other options might be to stockpile waste rocks or concrete rubble for potential future use for breakwaters and seawalls.

According to EU (2009) almost 40 percent of the population in Europe lives near coasts. The impact of climate change on coasts, marine and freshwater is very important. Every region experiences some risks, whether tidal surges, coastal erosions, hurricanes and tropical storms, sea level rise, increased drought, saltwater infiltration of aquifers, or heat waves. Though there local and regional variations, the Southern Atlantic and the Mediterranean are the most affected regions of Europe. According to EU (2009) there is an urgent need of adaptation for coasts and marine areas to be considered in the integrated maritime policy and the marine strategy framework directive, and for the common fisheries policy and common agricultural policy. This will also includes a series of risk management actions, starting with the proactive measures and then becoming reactive. The actions will focus on prevention, preparation, response and recovery.

2.2.13 Coastal zone issues based on continental perspective

Africa has suffered multiple severe climate fluctuations (temperature, floods, and droughts, with consequences such sea level rise), some of which were intensified by progressive climate change. These variations particularly affect the poor, who lack the resources to prepare for and recover from changes. For the poor, it is unrealistic to plan for the long-

term impacts of climate change until strategies for dealing with short-term climate variability are in place. According to UNEP (2002) future sea level rise has the potential to cause huge impacts on the African coastlines including the already degraded coral reefs on the Eastern coast. National communications indicate that the coastal infrastructure in 30 percent of Africa's coastal countries, including the Gulf of Guinea, Senegal, Gambia, Egypt, and along the East-Southern African coast, is at risk of partial or complete inundation due to accelerated sea level rise caused by changing weather patterns. According to UNEP (2002) some of the adaptation measures includes: (a) The coastal climate outlook and adaptation recommendations be incorporated into a coastal climate adaptation response plan focused at the local level that will include actions before and during or after a severe climate event (b) Supportive policy and institutional issues will be identified to enable this and will include national and local level institutions for natural resource and coastal management, disaster preparedness and risk reduction, sectoral ministries and other relevant offices.

2.2.14 Coastal zones issues based on regional perspective

According to Theron (2007) Southern Africa coastline are expected to have a slightly lower maximum wave run-up of <6m because of differing wave regimes, storm power and direction. The combination of sea-level rise and storm surges will have the biggest impact on people and their livelihoods. Increased storminess due to climate change would impact costs, protection and increase the difficulty of coastal mining and fishing in certain areas. However, it appears that apart from some important potential impacts in the Walvis Bay area, the Namibian coastline is relatively less vulnerable to climate change as compared to other countries (Theron, 2007). According to Theron (2007) the adaptation options in Southern Africa includes: planning and research-related initiatives, such as quantifying increased storminess, and determining appropriate coastal erosion and development setback lines and ensuring no vulnerable structures are located within the flood zones

2.2.15 Coastal zones issues based on national and provincial perspectives

According to DEA (2010) South Africa coastal environmental is already experiencing change. Sea-level is rising around the South African coast, but there are regional differences. The west coast is rising by 1.87 mm per year, the south coast by 1.47 mm per year, and the east coast by 2.74 mm per year (DEA, 2010). This variation in change is confirmed by climate models that shown some areas along the coastline to be more susceptible to sea level rise than others. There are also a significant proportion of South Africa metropolitan areas which are coastal and make them vulnerable to dramatic sea rises. It was emphasised by SANBI (2007) that this metropolitan areas will results in increased human pressure on coastal areas and will need sustainable coastal development through integrated coastal management approach.

According to Tol (2004), by 2100 South Africa would lose some 11 percent of its wetlands due to full coastal protection measures and structures erected to adapt and mitigate sea level rise impacts, making South Africa potentially the 5th most vulnerable country worldwide in terms of wetland losses. The most vulnerable areas identified are (a) Northern False Bay (b) Table bay (c) Saldanha bay (d) South coast bay (e) Mossel bay (f) Port Elizabeth and (g) Developed areas of the Kwazulu Natal coast (Theron, 2007). South Africa has experienced significant declines in catches and loss of species as a result of sea level rising, and due to fish populations migration related with climatic changes (DEA, 2010). This has compromised food security in coastal areas around the country.

According to Tol (2004), in South Africa for example by 2100 the country would lose some 11 percent of its wetlands due to full coastal protection measures and structures erected to mitigate sea level rise impacts, making South Africa potentially the 5th most vulnerable country worldwide in terms of wetland losses. The most vulnerable coastal areas due to climate change that have been identified are Northern False Bay, Table Bay, Saldanha Bay, the South Cape coast, Mossel Bay to Nature valley and developed areas of the Kwazulu Natal coast (Hughes *et al.*, 1991; Hughes *et al.*, 1993; Midgley *et al.*, 2005 ; Brundrit, 2008; Cartwright , 2008).

The Cape coast is more vulnerable to inundation and salt-water intrusion, while the risk on the KwaZulu-Natal coast is more likely to be erosion. Private housing is most at risk in the Southern Cape and commercial property in KZN. It was estimated that coastal storm damage along Durban coast due to 2007 extreme weather event was greater than R100 million and damage to residential property in Western Cape to sea rise was R10 – R100 million (Theron and Rossouw, 2009). These changes in sea temperature, sea level, acidity and storm events either individually or in combination will all influence indigenous and non indigenous biodiversity (Clark, 2006; Smith *et al.*, 2007 and Rouault *et al.*, 2009).

According to Theron (2007) some adaptation measures includes the following: breakwaters, revetments and sea walls, which protect infrastructure such as harbours and houses from direct wave action and under scouring; there is also a relief of much of the South Africa coast and the location of existing developments resulting in relatively few developed area sensitive to flooding and inundation resulting from projected sea level rise.

2.2.16 Health issues based on international perspective

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 (Martens *et al.*, 1999). The global burden of climate change-attributable diarrhoea and malnutrition are already the largest in the world in Southeast Asian countries including Bangladesh, Bhutan, India, Maldives, Myanmar and Nepal in 2000 (Martens *et al.*, 1999). Illness and death are expected to increase from diarrhoeal diseases due to drought and flooding, and are also expected from increased amounts of cholera bacteria in coastal waters. There is also heat stress and changing patterns in the occurrence of disease vectors which is affecting health. Asia has developed a regional action plan to human health from the impact of climate change. According to WHO (2009) some of the action taken includes: (a) To increase financial support to strengthen health programmes that are already addressing climate sensitive diseases and environmental health (b) To develop and ensure swift implementation of integrated national action plans focusing on concrete public health interventions that would address the impacts of climate change on health and to collaborate with other sectors and stakeholders and actively participate in ongoing

processes that are addressing climate change issues to streamline health concerns at national, regional and global levels, including the United Nations Framework Convention on Climate Change.

According to Ahem *et al.*, (2005) the main risks of climate change on health and life in South America are from heat stress particularly due to urban heat island effects in megacities and transmissible diseases including malaria, dengue and cholera. Expected increases in forest fires due to warmer, drier climate and increased deforestation and forest fragmentation are likely to heighten the vulnerability of the population to the health impacts of biomass burning smoke, the effects of which have already been observed in Brazil (Haines and Patz, 2004). Adaptation measures employed in South America includes the following: (a) A project on adaptation to climate variability and change which is oriented towards formulating measures to reduce human health vulnerability and cope with impacts (Arjona, 2005) (b) The development of a comprehensive and integrated dengue and malaria surveillance control system, aiming to reduce the infection rate from both diseases by 30 percent (Mantilla, 2005) (c) Vector control and medical surveillance whose aim is to have community participation and health education, entomological research, strengthened sanitary services and (d) The development of research centres dealing with tropical diseases (Aparicio, 2000).

According to 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. But the governments in North America has identifies excellent adaptation measures against changing weather patterns. According to USEPA (2010) the following adaptation measures are important to adapt: (a) Many diseases and health problems that may be exacerbated by climate change can be effectively prevented with adequate financial and human public health resources, including training, surveillance, emergency response, prevention and control programs (b) Urban tree planting to moderate temperature increases (c) Weather advisories to alert the public about dangerous heat conditions and adjusting clothing and activity levels.

In Europe, the summer of 2003 was one of the hottest on record so far (IPCC, 2007). In France the temperatures exceeded 40°C, leading to over 14,000 deaths, with the vast majority being seniors. According to IPCC (2007) the extreme nature of the event caught France, as well as the rest of Europe, unprepared. There were no heat wave response plans, and individuals were unaware of how to protect themselves. Disease vectors (e.g. mosquitoes, sandflies and ticks) are highly sensitive to climatic conditions, including temperature and humidity are expected to shift in Europe, particularly at their latitudinal and altitudinal limits, meaning that certain vector-borne diseases may be introduced to regions that have not previously encountered them. According to EU (2010) the following adaptation measures are used against climate change in Europe: (a) The strengthening of effective surveillance and prevention programmes in areas at risk of new diseases, (b) Sharing lessons, (c) Early warning systems, data and information across countries and sectors on prevention of extreme events, (d) Development of climate change risk management practices in health care systems and (e) Awareness raising and risk communication.

According to Nicholls and Alexander (2007) floods in Australia has lead to increased spread of mortality vector borne and infectious diseases, injuries and deaths. They further stressed that fewer but heavier rainfall event likely to affect mosquito breeding and increase variability in annual rates of Ross River Virus, particularly in temperate and semi-arid areas of Australia. The establishment of dengue fever is likely to increase through changes in climate and population sensitivity in both tropical and temperate latitudes. Demographic trends are likely to amplify these changes (IPCC, 2001). According to ARC (2006) adaptation measures being used in Australia against climate change are as follows: (a) Use of early warning system, (b) Increased public education about risks and behaviours, (c) Designed urban environment to reduce the heat island' effect (d) Ensured an adequate supply and appropriately located health-care facilities, (e) To increase mosquito control, (f) To develop vaccines and to improve monitoring / surveillance.

2.2.17 Health issues based on continental perspective

Africa is vulnerable to a number of climate sensitive diseases including malaria, tuberculosis and diarrhoea (Guernier *et al.*, 2004). Under climate change, rising temperatures are changing the geographical distribution of disease vectors which are migrating to new areas and higher altitudes, for example, migration of the malaria mosquito to higher altitudes will expose large numbers of previously unexposed people to infection in the densely populated east African highlands (Boko *et al.*, 2007). Again according to Harrus and Baneth (2005) future climate variability will also interact with other stresses and vulnerabilities such as HIV/AIDS. Floods are also expected to increase infectious diseases like cholera, diarrhoea and malnutrition for adults and children (WHO, 2004). In Africa in order to adapt against climate change there should be a serious commitment from international communities to help to adapt to the health threats through improving health services. According to Boko *et al.*, (2007) adaptation measures in Africa should focus on reducing vulnerability and/or increasing the adaptive capacity of communities to the health impacts of climate change and variability. This includes piloting measures, institutional strengthening, and/or capacity building.

2.2.18 Health issues based on regional perspective

According to IPCC (2001) climate change in Southern Africa has critical health implications. Changes in rainfall will affect the presence and absence of vector- and water-borne pathogens. For instance it can be expected that small changes in temperature and precipitation will boost the population of disease-carrying mosquitoes and result in increased malaria epidemics (Lindsay and Martens, 1998). According to Warsame *et al.*, 1995 increased flooding could facilitate the breeding of these malaria carriers in formerly arid areas (Warsame *et al.*, 1995). The challenge of population expansion has outpaced the capacity of municipal authorities to provide civic works for sanitation and other health delivery services across Southern Africa. It was therefore emphasised by WHO (2004) that for Southern Africa to adapt against changing weather conditions the following strategies are vital: Surveillance of crop productivity, in-stream flow rates, water tables, food consumption, rates of malnutrition and population movements will be as important to track as changing distributions of vector-borne disease, water-related disease and other

infectious diseases. These types of surveillance will be an important part of improving early warnings of climate impacts so that resources can be targeted to address emerging threats, targeted human development policies and programs, including better access to education, credit, health care, and reproductive services for women, will improve livelihoods and reduce social pressures and finally there is an urgent need for more research to model the health impacts of climate change in specific locations, evaluate approaches to reducing vulnerability and perform analyses of the cost-effectiveness of different adaptation approaches.

2.2.19 Health issues based on national and provincial perspectives

According to WHO (2004) water scarcity and its consequences of reduced water quality is another significant threat to human health in South Africa. Floods and wind storms are expected to disrupt water-supply, sanitation systems health-care and causing new breeds sites for mosquitoes. It is also expected in provinces like Limpopo that drought will results in less water for hygiene, reduce food supplies which will result in malnutrition and will result in fires thus reducing air quality (Lipp *et al.*, 2002). The South African government has developed positive adaptation measures across its provinces: to reduce the incidence of respiratory diseases by improving air quality, to ensure that sound nutritional policies, health care infrastructure and education lie at the heart of all the health adaptation strategies by acknowledging that if a population's nutritional status is robust, individuals will have greater resilience, to develop and rollout public awareness campaigns on the health risks of high temperatures and appropriate responses including, improved ventilation and avoidance behaviour , to design and implement "Heat-Health" action plans including plans in respect of emergency medical services, improved climate-sensitive disease surveillance and control, safe water and improved sanitation, to strengthen information and knowledge of diseases-climate linkage, to develop a health data capturing system that records data both at spatial and temporal scales and that ensures that information collected can be imported into multiple-risk systems such as the South African Risk and Vulnerability Atlas electronic spatial database system, to improve the bio safety of the current malaria control strategy and to strengthen the awareness programme on Malaria and Cholera outbreaks.

According to DEA (2010) the adaptation to resolve the twin plague of malnutrition and infection requires a multi-sectoral integrated approach. Programmes directed at improving public health and immediate and long-term food security and nutritional strategies should receive focused attention as they will contribute to building resilience to climate change (DEA, 2010). Otherwise this will lead to decreased agricultural production because of sick or unhealthy people who cannot engage in food production.

According to LIM (2004) South Africa is going to become generally drier and warmer through climate change and significant impacts are expected in some sectors, particularly agriculture, water resources, biodiversity and human health. These potential impacts will undoubtedly have detrimental effects on South Africa's priority issues (i.e. poverty alleviation, employment, housing, access to and provision of services, food security, potable water, HIV/AIDS, etc.). Climate change could make 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).

According to DEA (2010) outbreaks of cholera have been associated with increasing episodes of droughts and floods, especially in high-density populations with poor medical infrastructure, and results in morbidity and mortality. The increasing numbers of hot days and nights, heat stress is likely to have detrimental effects in vulnerable populations, children and the elderly, especially in locations of poor housing infrastructure resulting in lack of labour in the agricultural sector (DEA, 2010).

It has been noted by Tshiala *et al.*, (2011) that malaria in Limpopo province has undergone a spatial change; as a result of climate change. There are models that show that increases in temperature and change in rainfall patterns are already favouring the range expansion of some vectors – borne diseases such as malaria. Furthermore a fifty-year analysis of temperature in Limpopo Province revealed an increase in the frequency of heat waves that could potentially lead to an increase in deaths in the elderly and young children especially in those occupants of poor housing (Tshiala *et al.*, 2011).

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. This has prompted Olwoch (2009) in her presentation during climate change summit in South Africa that in tackling climate change and health it needs cooperation between climatologists , ecologists , entomologists and medical practitioners, so that we fully assess which diseases affects humans , where they are , where they are going and how to adapt.

2.3 Impact of climate change on livestock, crop yields and crop prices

2.3.1 Climate change impacts on livestock production based on international perspective

The livestock industry represents 40 percent of agricultural production worldwide and provides a livelihood and food security to one billion people (IPCC, 2007). Climate change could have an impact on livestock and dairy production. The pattern of animal husbandry may be affected by alterations in climate, cropping patterns, as well as ranges of disease vectors. The higher temperatures would likely result in decline in dairy production, reduced animal weight gain, reproduction and lower feed-conversion efficiency in warm regions. More mixed impacts are predicted for cooler regions. If the intensity and length of cold periods in temperate areas are reduced by warming, feed requirements may be reduced, survival of young animals enhanced and energy costs for heating of animal quarters reduced.

Climate change could also affect livestock by disease. Incidence of diseases of livestock and other animals are likely to be affected by climate change, since most diseases are transmitted by vectors such as ticks and flies, the development stages of which are often heavily dependent on temperature. Cattle, goat, horse and sheep are also vulnerable to an extensive range of nematode worm infections, most of which have their development stages influenced by climatic conditions across the globe.

According to Hall (2009) climate change impacts will be overwhelmingly severe for Asia. Asia's rapidly growing population is already home to more than half of humanity and a large portion of the world's poorest people. Climate change had started threatening development in the region and could continue to put livestock production and food security at risk by the 2020s (Hall, 2009). According to FAO (2003) climate change is a serious problem in Asia, since Asia produces more than half of pork consumed in the world and it has overtaken Europe in terms of milk production. It is under this conditions that Asia is under pressure to put strategies in place to adapt to climate change. Given that the livestock production system is sensitive to climate change and at the same time itself a contributor to the phenomenon, climate change has the potential to be an increasingly formidable challenge to the development of the livestock sector in Asia. It is further emphasised by Siroli and Michaelowa (2007) that the anticipated rise in temperature between 2.3 and 4.8°C over some of Asia's country's together with increased precipitation resulting from climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance, and hence reducing the total area where high yielding dairy cattle can be economically reared.

2.3.2 Climate change impacts on livestock production based on continental perspective

According to (Herrero and Thornton 2009) the bulk of agriculture studies on the effect of climate change have focused on crops. However, a large fraction of agricultural output is from livestock. Almost 80 percent of African agricultural land is used for grazing hence African farmers depend on livestock for income, food, animal products and insurance.

According to Delgado *et al.*, (1999) livestock systems in Africa are changing rapidly in response to a variety of drivers. Globally, human population is expected to increase from around 6.5 billion today to 9.2 billion by 2050 (IPCC, 2007). More than 1 billion of this increase will occur in Africa. Rapid urbanisation is expected to continue in developing countries, and the global demand for livestock products will continue to increase significantly in the coming decades (Delgado *et al.*, 1999). In addition, the climate is changing, and with it climate variability and this adds to the already considerable development challenges faced by many countries in Africa.

The impacts that climate change in Africa will bring about are 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, biofuels, etc). For rural communities losing livestock assets might lead to the collapse into chronic poverty with long-term effects on their livelihoods. Again in Africa, by contrast, the bulk of livestock have no protective structures and they graze off the land. There is every reason to expect that African livestock will be sensitive to climate change (IPCC, 2007).

2.3.3 Climate change impacts on livestock production based on regional perspective

According to Thornton *et al.*, (2006) in Southern Africa livestock production is prone to climate change impact. The impacts of climate change on livestock are 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 impacts food and livelihood security of those who own livestock. In times of water scarcity, when livestock are forced to use the same water resources as humans, diseases are transferred between humans and animals and vice versa. Where livestock practices alter local vegetation cover, this in turn affects local climate. The impact of climate change will have a negative impact in Botswana, South Africa and Namibia which are involved in large – scale livestock production. It will also hamper this countries meat export to European economic communities' countries. This situation prompted Herrero and Thornton (2009) to conclude that farmers in Southern Africa should manage water resources properly, change to alternative feeds and breed livestock that can adapt to the variable climatic conditions.

2.3.4 *Climate change impacts on livestock production based on national perspective*

According to DAFF (2011) livestock is the largest agricultural sector in South Africa, with a population of some 13.8-million cattle and 28.8-million sheep. The livestock sector contributes up to 49 percent of agricultural output. There are, however, provinces that are experiencing abnormally dry periods which negatively affect animal production, especially parts of the Free State, Eastern, Northern and Western Cape. This drought is expected to reduce livestock production through mortalities and distress sales. According to DAFF (2011) there is a mortality difference between small scale and commercial farmers, which is a reflection of commercial farmers better access to grazing, water, high cash reserves to buy in feed or rent grazing and greater willingness / ability to sell animals. About 25 percent of emerging farmers in South Africa reported selling some livestock during drought in 2010, and half of 25 percent sold more than normal because of drought. This is an indication that resource poor farmers are at risk from climate change because they don't have adaptation measures as compared to commercial farmers.

According to Brown – Brandl *et al.*, 2005, Chase (2006); Christensen *et al.*, (2007) livestock and livestock products contribute an estimated 51 percent of the agricultural income, mainly from the intensive livestock sector. They further said to estimate the effects of climate change on the livestock sector; several approaches and simulations have been used in South Africa to develop heat stress (maximum ITH) and humidity (THI) indices for livestock. The heat stress in pigs was found to be as a result in small reduction in growth rate with piglets taking one day longer to reach target weight; there is also a 10 percent heat stress increase and 10 percent increase in energy consumption in boilers and feedlot and dairy cattle are adversely affected by high temperature, relative humidity, solar radiation and low wind speeds (Christensen *et al.*, 2007).

2.3.5 Climate change impacts on livestock production based on provincial perspective

According to Mpandeli *et al.*, (2007) livestock plays a major role in most rural parts of Limpopo province. Mpandeli *et al.*, (2007) further emphasised that some households use livestock for different purposes: draught, transportation, ceremonial and bride wealth but the situation is now changing as a results of poor rainfall distribution in the province. It was further emphasised by LDA (2010) that small – scale farmers who are dealing with livestock predominate in the province have little capital and will not be able to pursue new strategies that will be required to adapt to climate change. Climate change in Limpopo province is raising temperatures, reduces rain and its timing. This in turn is putting pressure on the province scarce resources, with implications for agriculture production. It is thus important to enable adaptation in the livestock sector particularly in Limpopo province where livestock sector is a critical component of the formal and informal economy.

2.3.6 Climate change impacts on crop yields based on continental perspective

According to IFPRI (2009) the negative impacts of climate change on crop yields are pronounced in Africa, as agriculture sector accounts for a large share of gross domestic product, export earnings and employment. The crop model indicates that in 2050 in most parts of Africa, average rice, wheat and maize yields will decline by up 20 percent, 25 percent and 30 percent respectively (IFPRI, 2009). This matter is further supported by Kalaugher (2010) when she said climate change will reduce production of five staple crops in Africa – maize, sorghum, millet, groundnut and cassava – by a mean of between 8 and 22 percent. And in all cases except cassava there's a 5 percent chance that yields could drop by more than 27 percent. Again Lobell (2010) emphasised that already Africa could face a 30 percent decline in maize production in the next two decades because rainfall and temperature in Africa is changing quite fast. The following statements issued by various organisations are a very serious concern.

2.3.7 *Climate change impacts on crop yields based on regional perspective*

According to Lobell *et al.*, (2008) the impact of climate change is highly variable on different types of crops. In Southern Africa declines in production of 15 percent for wheat and 27 percent for maize in the absence of any agricultural adaptation to climate change have been projected (Lobell *et al.*, 2008). Farmers have already felt the first effects of changing climatic conditions. In 2006, the production of maize, the main staple in the region, fell short by 2.18 million metric tonnes due to droughts in Namibia, Mozambique, Swaziland, Zimbabwe and South Africa (Musvoto, 2009). She further emphasized that flooding in the Zambezi basin has been affecting Angola, Botswana, Namibia, Zambia and Zimbabwe. Both Seychelles and Zambia have been experiencing a mixture of increased droughts and increased flooding. According to Schulze and Horan (2010) preliminary analysis in Southern Africa demonstrates that both timing and amount of rainfall is a good predictor for yields and that potential future decreases in total rainfall in early winter months will have a negative impact of between 5 and 70 percent on yields, depending on area and eventual climate change scenario.

2.3.8 *Climate change impacts on crop yields based on national perspective*

The grain industry is one of the largest in South Africa, producing between 25 percent and 33 percent of the country's total gross agricultural production (GSA, 2010). The largest area of farmland is planted with maize, followed by wheat and, to a lesser extent, sugarcane and sunflowers. According to StatsSA (2007) maize production contributed to 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 – 20 percent over the next 50 years (BFAP, 2007).

According to Walker and Schulze (2008) Yields are likely to be sensitive to both climate and CO₂ fertilization, with doubled CO₂ offsetting much of the reduced profitability associated with a 2°C temperature rise or a 10 percent reduction in rainfall, especially in core areas of maize production in South Africa. There is also a projected temperature increase, which will cause 28 percent restriction of the some areas suitable for production as early as 2020 (Vogel *et al.*, 2010).

All the above scenarios are consistent with observed trends of reduced production and exports partly ascribed to adverse conditions (Midgley *et al.*, 2005).

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

The following quotes show the impact of climate change on crop yields:

"This comes after R130 million worth of potatoes and tomatoes failed to make it to local and international markets because they were damaged by frost before harvesting. It's the first time in 40 years that frost smashed our production" – NAFU (2010)

"The continuous adverse weather patterns, particularly the heavy rains early in 2010, resulted in major delays in harvesting" – McCain Foods SA (2010)"

The crop was further compromised by a black frost in mid-June, and again in mid-July which will result in prolonged problems with potatoes that are not fully matured, through to the end of November 2010." – McCain Foods SA (2010) "

We have already utilised the global McCain network to import frozen potato chips to keep our customers in stock, but unfortunately our fellow farmers in the UK and Europe are also experiencing nature at its worst" - - McCain Foods SA (2010)

2.3.9 Climate change impacts on crop yields based on provincial perspective

Limpopo province is the main tomato growing area in South Africa, producing 66 percent of the total annual tonnage of tomatoes (NDA, 2009). But according to Tshiala and Olwoch (2010) there is an increase of tomato production in Limpopo for certain years and there are some decrease of production in certain period because of the sensitivity of the tomato crop to climate variability and change. The reduction in tomato production in some of the years was mainly due to droughts experienced in the region. Farmers in Limpopo province are thus facing a possible negative impact on crop yields, especially farmers without advanced technology and good modern agricultural practices (Tshiala and Olwoch, 2010). As a consequence, less food is directly available to the household. People in the province linked changes in food production and availability to decreased health, which is in turn linked to climate, water and economic/financial stresses. Some communities are moving away from agriculture/horticulture and are instead seeking to engage in wage earning activities as an adaptation to water and climate stresses.

The following quotes show the impact of climate change on crop yields:

“Tomato farmers in Limpopo province say they have lost between R10 million and R50 million as heavy rains continue to wreak havoc on the crops” – TGA – 2010

“Experts have warned that some crops may experience difficulties as the rate of climate change increases” – TGA – 2010

2.3.10 Impacts of climate change on crop prices based on continental perspective

According to FAO (2010) African nations make up 36 of the 50 nations whose food supplies are most at risk. Extreme droughts and high poverty rates, as well as poor infrastructure for transporting agricultural products, render Africa particularly vulnerable to high food prices. According to FAO (2010) Africa is struggling in terms of crop prices to climate change. The price rises have been most pronounced with the cereal crops — maize, wheat, rice, sorghum and millet — that comprise the basic diet

of billions of people. They have also hit feed for cattle, chickens and other meat-producing animals (FAO, 2010).

Again according to FAO (2009) food price index rose by 47 per cent between January 2007 and January 2008 – led by increases in the prices of cereals (62 percent), dairy (69 percent), and vegetable oils (85 percent).

2.3.11 Impacts of climate change on crop prices based on regional perspective

According to Hachitonga (2009) since 2007, erratic rainfall has led to increased food shortages in Southern Africa where droughts damaged and destroyed maize crops in Lesotho, Namibia, Mozambique, Swaziland, Zimbabwe and South Africa. As a result, Southern Africa faced a shortfall of 2.18 million metric tonnes of maize in 2006 and, as results people in Southern Africa lacked more than 4 million metric tonnes of maize in 2007/2008 thus increasing maize price due to scarcity. According to CSAG (2009) rises in food prices in 2007 and 2008 led to riots in some Southern Africa countries over food shortages and prices came down after that but are now rising again. This situation was further emphasized by Word Bank which released its food index data in March 2011, data showed higher food prices-mainly for wheat, maize, sugars and edible oils have pushed 44 million more people in developing countries including Southern Africa into extreme poverty since June 2010 due to climate change.

2570

2.3.12 Impacts of climate change on crop prices based on national perspective

There was a severe cold and frost that hit South Africa in 2010 due to unpredictable weather patterns and this has proved to be very costly to vegetable farmers. This situation was also worst in Kwazulu Natal of South Africa where according to Du Bruin (2010) sugarcane farmers were not spared the biting cold. It was confirmed that 124 000 tons of cane has been affected with first – fifth stage damage. And this is one of the reasons why the price of sugar has increased as shown by food price index released by World Bank in March 2011. In general South Africa's total maize output and the yield per hectare have fluctuated dramatically over the past three decades, in large measure because of droughts

(DAFF, 2011). This has led in some instance high maize price due to scarcity. Although yields per hectare have improved in recent years, this is partly thanks to energy-intensive inputs which will become increasingly expensive and scarce as oil progressively runs out. There were also continuous adverse weather patterns, particularly the heavy rains early in 2010, which resulted in major delays in harvesting of potatoes. According to McCainSA (2010) this has led to high potatoes price due to its scarcity.

2.3.13 Impacts of climate change on crop prices based on provincial perspective

Limpopo province is a main tomato growing area in South Africa, producing 66 percent of the total annual tonnage of tomatoes (NDA, 2009). The total annual production of tomatoes is about 227,990 tons of the total South African production which is 345,440 tons, that is two thirds of the national tomato production (NDA, 2009). According to Du Bruin (2010) frost damage in Limpopo province is extensive and a huge area in Sekhukhune and Capricorn district was badly hit. He further emphasized that the situation is going to be very terrible since some vegetables are now very expensive i.e. tomatoes are already up to R100/bag, green beans are nearly R50/Kg from R6/Kg – R70/Kg they normally sell.

2.4 Impacts of climate change on food security and farm income

2.4.1 Impacts of climate change on food security based on continental perspective

Climate change is projected to severely compromise agricultural production - the backbone of most African economies - and exacerbate poverty and food insecurity in many sub-regions of the continent. According to Niasse *et al.*, (2004) Africa is considered the most vulnerable region in the world in terms of climate change, because some of its physical and socio-economic characteristic, for instance, the fragility of its economy, predisposes it to be disproportionately affected by adverse effects of climate change. Again according to FAO (2009) countries in Africa will be 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).

As extreme weather events in Africa are likely to become more frequent and of higher intensity due to ongoing climate change, this situation may only get worse. It would appear that African countries are likely to continue to dominate the food security risk index for some time and businesses with operations and supply chains in Africa should plan for ongoing uncertainty around food and all its related problems, not least geo-political risks.

2.4.2 Impacts of climate change on food security based on regional perspective

Climate change affects Southern Africa food systems in the broadest sense of the word. "It affects the availability of, access to and utilisation of food," (Ziervogel, 2008). She further emphasise that changing weather patterns or extreme events such as floods or droughts will have a negative consequences for agricultural production in Southern Africa. As results people will have less access to food thus resulting in food insecurity. According to Lobell *et al.*, (2008) increasing temperatures and declining precipitation over Southern Africa are likely to reduce yields for corn, wheat and other primary crops in the next two decades. These changes will have a substantial impact on regional food security. This food crisis in Southern Africa has been caused by low and unseasonal rainfall in Malawi, Zambia and Zimbabwe.

In some places, crop failure as been as high as 90 percent and maize prices have risen by up to 400 percent. Climate change has not only impinges on the cultivation of crops. According to Ziervogel (2008) the fishing industry is being threatened as well. She stressed that fish stocks in large lakes across Southern Africa have declined – not only because of overfishing but because of declining water levels due to evaporation as a results of rising temperature.

This situation was also emphasised by Vogel *et al.*, (2007) that there is chronic and persistent food insecurity in Southern Africa. Vogel *et al.*, (2007) further explained that for example the 2002/2003 drought in Southern Africa contributed to food shortages for an estimated 14 million people. This situation was as a result of below normal rainfall for two to three agricultural seasons which had an impact in many parts of Southern Africa. The above growing crisis has triggered the United Nations to issue an appeal for US\$611 million to address the crisis especially in Lesotho,

Malawi, Swaziland, Zambia, Zimbabwe and Mozambique (SARPN, 2004; House of commons, 2003).

2.4.3 Impacts of climate change on food security based on national perspective

According to (DEAT, 2004) food production of maize, South Africa's staple food could drop by as much as 30 percent in the next two decades as climate change brings more intense droughts. In the densely populated rural areas of KwaZulu-Natal Province on the east coast, the largest agricultural contributor to South Africa's gross domestic product (GDP), small-scale farmers dependent on rain-fed agriculture were found to be among the least resistant to climate change. Farmers in Limpopo Province, in the North West, and Eastern Cape Province, on the southeast coast, were also vulnerable (Gbetibouo *et al.*, 2010). The farmers in those provinces have less resilience because the areas they live in are undeveloped, with no means to access drought-tolerant crop varieties. This was further emphasised by Molewa (2011) that climate change is threatening food security and pushing up food prices. She concluded that climate change effects are continuing to impact negatively on our food security and the recent price increases are mainly as a result of climate change.

The food security situation in South Africa was further emphasised by Molope (2006) that the country is particularly vulnerable to climate variability and change as agricultural production depends on climatic conditions and largely on the quality of the rainy season. According to Joemat - Pettersson (2011) the food security threat posed by climate change is one of the greatest challenges facing South Africa. She further mentioned constraints such as severe drought, floods and dreadful diseases as obstacles to food security. Agricultural sector is facing impacts that include: (a) A reduction in the amount of land suitable for both arable and pastoral agriculture, (b) A shortening of the growing season and a decrease in yields particularly along the margins of semi arid and arid areas (Joemat – Pettersson, 2011). This will compromise food security badly and climate change impacts will further reduce the sectors contribution to the gross domestic product, which has already been declining over the years. According to South African Country Study Programme (2011) climate change impacts on the agricultural sector thus not only have implications for the national and household food security but the economy as well.

2.4.4 Impacts of climate change on food security based on provincial perspective

According to Nesamvuni *et al.*, (2003), Limpopo province constitutes 18 percent of the 40 percent (about 16 million) people of South African living in outright poverty or continuing vulnerability to being poor food shortages. Again according to CSAG (2009) farmers in Limpopo province will experience rain more than a month later within the next three decades. The province is also experiencing more hot days and fewer cold days as a result of climate change. Since 2007, erratic rainfall has led to increased food shortages in some parts of the province because droughts damaged crops (NDA, 2009). It is also estimated that maize yields in Limpopo province will decrease by approximately 9 percent between now and 2045 (Hachigonta, 2010). This predicted decline will pose a major problem for food security, as maize is Southern Africa's main staple food.

2.4.5 Impact of climate change on farm income based on continental perspective

According to Seo and Mendelssohn (2006) the rise in temperature in Africa could reduce the income of large- scale farmers by as much as 35 percent or US\$20 billion a year compared to 2006. Again increased rainfall would reduce livestock revenue for both large and small farms. Agricultural production is projected to be halved – developments that will threaten the livelihoods and income of farmers in the region, where majority of the population are smallholder farmers. According to Mendelssohn *et al.*,(2000) farmers are already feeling the impact of climate change on their income because in 2006, the production of maize fell short by 2.18 million metric tonnes due to droughts in some part of Africa. As results Musvoto (2009) emphasise that farmers should diversify their income if they want to survive and if possible farmers should seek work elsewhere because they can't rely on agriculture anymore.

2.4.6 Impact of climate change on farm income based on regional perspective

Environmental researchers predict Southern Africa will be hit heavily by climate change over the next 70 years. Agricultural production is projected to be halved - a development that will threaten the income of farmers in a region where 70 percent of the population are smallholder farmers.

Southern Africa is already experiencing declining incomes and increased likelihood of food insecurity. Climate change is likely to make things worse for farmer's income. Southern Africa vulnerability is in good part a function of its having higher climate variability than other regions of the world, such as Central Africa and Europe (UNFCCC, 2008). According to Musvoto (2009) farmers have already felt the first impact of changing climatic conditions in 2006 when their income fell dramatically due to droughts in Namibia, Mozambique, Swaziland, Zimbabwe and South Africa.

2.4.7 Impact of climate change on farm income based on national perspective

According to Blignaut *et al.*, (2009) South Africa is getting hotter and dryer and this has major implications for South African agriculture. Notably, there is very little scope for expansion of irrigation, given the limited supply of water and the pressing socio-economic needs. This implies that farmers are likely to rely more and more on water-saving techniques that may drive up cost even further in a sector that has a small net income margin and which is already facing rapid cost increases due to climate change. This is likely to make it increasingly difficult for farmers to improve their income from agriculture. They further emphasise that net agricultural income in the provinces contributing 10 percent or more to total production of both field crops and horticulture is likely to be negatively affected by a decline in rainfall. In South Africa each 1 percent decline in rainfall is likely to lead to a 1,1 percent decline in the production of maize (summer grain) and a 0.5 percent decline in wheat (winter grain) thus leading to very low farmers' incomes (Blignaut *et al.*, 2009).

2.4.8 Impact of climate change on farm income based on provincial perspective

There are sparse rainfall and high evaporation rates in Limpopo province that limits the success of farming activities, which include growing maize, pumpkins, rearing cattle's goats and chickens (Ziervogel, 2008). This will in turn affect farmer's income. Ziervogel (2008) further emphasise that in Limpopo province agricultural incomes are lowest due to climate change as compared to non-agricultural incomes. This is mainly due to the fact that climate change affects agricultural production directly. It is also identified that climate change will have a major impact on farmer's income, particularly in rural areas of

Limpopo province where agricultural production is the major source of income and employment (Maponya, 2008). Limpopo province is further vulnerable because of their limited ability to adapt to climate change due to dependence of rainfed agriculture in some areas, low levels of human capital, physical capital, and poor infrastructure.

2.5 Summary

- 1) This chapter has introduced theoretical and empirical studies relating to climate change adaptation. Climate change is fast pushing the poorest and most marginalized communities beyond their capacity to respond. This chapter also draws on lessons learned and experience across the globe. This chapter also demonstrate that climate change is a cross cutting issue, it affects and threatens several sectors including agriculture. It sets out what is needed to enable people living in poverty to adapt to climate change, and a range of interventions that are available.
- 2) The chapter also looked at various climate change adaptation in other sectors like water resource, health, ecosystems, coastal etc which is expected to develop greater capacity to manage risk, uncertain conditions and therefore to adapt more readily to new and different conditions. In the response to challenges faced by water sector as results of climate change, the South African government is planning to do the following across its nine provinces:(1)To develop and maintain good water management systems (2) Water related infrastructure and institutions from village through to national level (3) To accelerate the development and/or capacity of effective and accountable catchment management agencies (4) To invest in monitoring capabilities across a range of disciplines in order to spot trends and understand them as well as track the efficacy of adaptive strategies (5) To optimise the re-use of wastewater (6) To increase investments wastewater treatment capacity to meet stipulated norms and standards for waste discharge (7) Develop and implement an household rainwater harvesting incentive programme (8) To develop early warning system and (9) To develop and rollout more effective support mechanisms to ensure that safe drinking water is available to all with a priority of ensuring that affordable access for all is safeguarded.

- 3) Biodiversity and ecosystems were also discussed in this chapter where climate change is expected to cause major shifts of many species as well as increase in extinctions. Ecosystems changes are already being detected in Southern Africa, at a faster rate than anticipated as a result of climate change. As a results the following adaptation measures were recommended in the chapter:(a) To develop and test methods to project the dynamic response of biodiversity to climatic change (b) To develop conservation planning tools for the prioritization of conservation planning in an environment which is non-static as a result of climate and land use change (c) To evaluate in terms of economic costs and effectiveness adaptation options for biodiversity conservation when faced with climate change and a fragmented landscape (d) To advance the field of dynamic biodiversity and ecosystem conservation and (e) To develop capacity in both the research and management communities to address climate change issues in a proactive and effective way.
- 4) Coastal zones are expected to be affected by climate change. As a result sea level rise, changes in sea water temperature, salinity, wind speed and direction will alter fish breeding habitats and food supply for fish. The last sector discussed was health, which if it cannot adapt will lead to weak and unhealthy labour force resulting in few participation in food production. This has illustrated that climate change adaptation is possible in countries whereby there is strong financial support, good institutions, good governance and policies available. This was also supported by United Nations Framework Convention on Climate Change that said future decisions about climate change must assist developing countries in a streamlined, innovative and transparent way, with transfer of knowledge, technology and financial resources to adapt at all levels and all sectors.
- 5) This chapter has provided a literature review of the impact of climate change on the agricultural sector. In fact, it has documented some of the likely impacts of climate change on International, continental, regional, national and provincial agricultural sector. This chapter has shown that climate change will have a significant impact on agriculture, primarily through affecting livestock production, which represents 40 percent of agricultural production worldwide and provides livelihoods and food security to one billion people. Various sources in this chapter indicated that the impacts of climate change on livestock are 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 impacts food and livelihood security of those who own livestock.

- 6) The chapter also emphasised that agricultural crop yields and prices will also be affected by changing weather patterns thus resulting in food insecurity especially for those farmers with advanced technology and good modern agricultural practices. Various sources in this chapter agreed that the negative impacts of climate change on crop yields are pronounced in Africa, as agriculture sector accounts for a large share of gross domestic product, export earnings and employment.
- 7) Climate variability and change will also have a negative impact on farmer income and food security. The chapter has highlighted the fact that agricultural sector is facing impacts that include: (a) A reduction in the amount of land suitable for both arable and pastoral agriculture (b) A shortening of the growing season and a decrease in yields particularly along the margins of semi arid and arid areas. This will compromise food security badly and climate change impacts will further reduce the sectors contribution to the gross domestic product, which has already been declining over the years.

CHAPTER 3

Overview of the agricultural activities in Limpopo province

3.1 Introduction

According to Motsoaledi (2002) agriculture is one of the cornerstones of economic progress and was identified by the Limpopo provincial government as one of the three most important pillars of economic development including mining and tourism. The economy of Limpopo is characterised by a small and concentrated production base and a large consumer population with limited means in terms of income (LEDET, 2009). It has a high potential for economic development and is attractive to various kinds of investment. The agricultural and mining (income generation) sectors form the backbone of the Limpopo economy (LEDET, 2009). It was also noted that mining, manufacturing and trade sectors are the most significant contributors to economic growth in the province. The government sector remains an important contributor to the provincial economy by sustaining a large skills base, as well as through transfer payments from the national budget.

3.2 Economic environment status in the Limpopo province

The contribution of agriculture and forestry to the economy of the province is low at less than 3 percent, it is the second biggest employment sector providing almost 120 000 of the approximately 664 000 jobs in the province. The fact that agriculture is also place-bound and is also the backbone of the rural economy and of stability in the province (Trade and Investment Limpopo, 2009). The economic growth indicators for the province are excellent, as the province has outperformed all the other provinces in respect of economic growth since 1995 (LEDET, 2009). It is, however, important to realise that the size of the provincial economy as measured in terms of Gross Domestic Product (GDP) is still relatively small at approximately R63,6 billion, which is 6,5 percent of the national GDP of about R983 billion. The GDP per capita for the province is about R12 060 per person per annum, compared to the national figure of approximately R21 942 (LEDET, 2009).

3.3 General overview of the physical environment in Limpopo province

Limpopo Province covers an area of 123910 square kilometers, which is 10, 2 percent of the surface area of South Africa. It has a diverse topography, with many interesting and valuable environmental features. The broad terrain patterns of the province are characterized by the Limpopo Plain forming the northern half of the province and the Bushveld basin surrounded by the Central Highland, which is bordered to the east by the Great Escarpment and the Eastern Plateau slope (StatsSA, 2011). The province has specific features that stand out as significant scenic areas. These include the tablelands and escarpments of the Waterberg complex, the low mountains of the Soutpansberg range and the Blouberg. The mountainous areas of the province are of high scenic value and together with the Lowveld and northern plain areas have great eco-tourism potential for initiatives such as The African Ivory Route (LEDET, 2009).

Limpopo falls in the summer rainfall region with the western part semi-arid, and the eastern part largely sub-tropical. The western and far northern parts experience frequent droughts (Mpandeli, 2006). Winter season throughout Limpopo is mild and mostly frost-free. The province has limited surface and ground water resources. Water management areas are severely stressed and many people still do not have access to the accepted minimum supply of water. The province relies on ground water as a source of supply (LEDET, 2009).

3.4 General overview of the biological environment in Limpopo province

Limpopo Province falls within the greater savannah biome, commonly referred to as bushveld, with a small representation of grassland and forest biomes. The rich biodiversity of Limpopo can be attributed to its bio geographical location and diverse topography. Three regions unique to the province (centres of endemism) occur in Limpopo province. They are the Drakensberg Escarpment (including Wolkberg), Sekhukhuneland and Soutpansberg (LEDET, 2009). The natural forests occurring in Limpopo include about 19 000 ha of northern mist belt forest and a few small pockets of Afromontane forest. Turf thornveld and Pietersburg false grassveld are also important and threatened vegetation

types that occur in Limpopo. There are about 170 identified rare and threatened plants in the province, many of which are used as medicinal plants (LEDET, 2009).

Environmental constraints are a serious obstacle in the province. Rainfall is unreliable and drought is a recurring problem. At the same time climate change is having a significant impact on agriculture, thus encouraging an effective adaptation strategy. The negative effects of climate change to rainfall patterns, water availability in water stressed areas and biological degradation have potentially major implications for poor people and farmers in Limpopo Province. This is supported by Sonjica (2010) when she said "Climate change threatens to undermine many of the United Nation's Millennium Development Goals, which includes the eradicating extreme hunger and poverty, with severe consequences for the world's poorest people"

3.5 Farming enterprises in the Limpopo province

Limpopo Province is one of South Africa's richest agricultural areas. It is a major producer of vegetables. The subtropical climate enjoyed by much of the province gives rise to the cultivation of tea, coffee and fruits, especially tropical fruits. Forestry makes a major contribution to the economy, as do tobacco, sunflower, wheat, cotton, maize, and groundnuts. Livestock farming includes cattle ranching and game. The abundance of orchards with various sub-tropical fruits and nuts form the basis of a thriving agro-industrial sector (StatsSA, 2006)

The main farming enterprise in the Limpopo Province is the production of vegetables. Within the Province the production of vegetables contributes an average of about 22 percent to the gross income from agriculture and more or less 18 percent to the total gross income of vegetables in the RSA. According to StatsSA (2006) on the survey of large and small scale agriculture, there were an estimated 245,000 fruit farming and 349,000 vegetables crop operations in RSA of these 138,000 fruit farms operations (56.3 percent) and 87,000 vegetables crop operations (24 percent) were found in the Limpopo Province (Makhura, 2001).

According to StatsSA (2007) the composition of horticultural products in the province, it is clear that the production of vegetables is the most important (49.1 percent) followed by citrus fruits (25.9 percent) and subtropical fruits (15.5 percent). The Letaba in the Mopani district of the Province produces 75 percent of South Africa's mangoes and this may increase as more trees come into production (Makhura, 2001).

Again StatsSA (2006) further indicated that this area also produces 65 percent of the RSA papayas and tomatoes, 36 percent of its tea, and 25 percent of its citrus, banana and litchi. Over 50 percent of RSA avocado also come from this region. Nut production forms a small part of the gross income from agriculture in the province, yet it contributes about 43 percent to gross income from nuts in the RSA. The production of citrus and subtropical fruit contributes about 64 percent to the gross income from citrus and subtropical fruit in the RSA and the production of tea contributes 21 percent.

Different beans, peas, bambara nuts and groundnuts are grown. In small home gardens people grows vegetables like Swiss chard, tomatoes, pumpkins, watermelons, beet roots, and carrots. Some households have some fruit trees like mangoes, peach, citrus and banana. Home gardens can contribute up to 20 percent of an accounted horticulture production in the province (Makhura, 2001).

3.6 Farming systems in the Limpopo province

Farmers in the Province can be classified into the following groups; (a) Commercial and (b) Small scale. Over 60 percent of the farmers have been placed in the last category with the majority being females. Another 28 percent are described as small-scale. Less than 1 percent is large-scale commercial farmers. About 8 percent of the total number of farmers is viewed as being progressive (StatsSA, 2006). This means about 90 percent are either resource poor or small-scale farmers. Smallholders grow most cereals and pulses; the commercial sector concentrates on intensive cash crops or extensive livestock. These categories are based on the size of their farms, volume of the products that these farmers are producing in the province.

3.7 Farms categories in Limpopo province

3.7.1 *Commercial farms*

These farms are operated as business and run by owners or employed professional managers. Commercial farms vary in size, though most tend to be medium to large. Commercial farms are mechanised and consume significant volumes of inputs such as fertilizers and pesticides. These farms also have well-developed infrastructure and market outlets, and the farmers are represented in farm unions. This sector contributed 70 percent of the province's agricultural income.

3.7.2 *Small scale farms*

These types of farm are divided into the following:

3.7.2.1 *Emerging commercial farms*

These are farms in transition between subsistence and commercial farms. They are mostly the medium size farms (10-100 hectares), which comprise about 28 percent of farms and 33 percent of land area. However, there are also a number of small-scale and large-scale farms that fall within this category. They consume moderate levels of modern inputs and employ lower levels of labour in comparison with commercial farms.

3.7.2.2 *Subsistence farms / Resource poor farms*

These are mainly small-size farms, generally characterised by fragmented plots and concentrated in the former homelands. These farmers are largely utilised for production of food crops for domestic consumption, with limited surpluses sold in local markets. These farms lack adequate production and market infrastructure. The use of modern inputs on these farms is very limited, and household's members provide the main source of labour.

3.8 Infrastructure in the Limpopo province

Despite the perceived role of efficient infrastructure as critical element for economic growth, poverty reduction and the attainment of the millennium development goals, there is clear evidence that the provision of infrastructure in Limpopo province has been much

below standard in terms of quantity and quality. The lack of modern infrastructure is a major challenge to economic development in the province and constitutes a major impediment to the achievement of sustainable development and other vital objectives, such as revitalizing of agriculture (LEDET, 2009).

According to Mathale (2009) the needs are enormous. From rural roads, railways, irrigation systems, telecommunications, clean water, sanitation, energy and such as basic social infrastructure including health, education, banking and commercial services. Hundreds of households lack even the most fundamental amenities. This is particularly true in rural areas, where the majority of the people live. The burden also falls most heavily on women, who often must spend hours collecting wood for cooking and heating in the absence of electricity. Rural women walk an average of 6 kilometers daily to rivers and springs for water (Maponya, 2008).

3.9 Constraints and challenges facing farmers in Limpopo province

The challenge facing farmers in Limpopo province are numerous and known to all involved within the agricultural sector. The biggest challenge is to source adequate and timeous finance. But because of the high risk associated with other farmers like emerging farmers, most financial institutions are reluctant to finance them. Issues related to access to land, provision of adequate infrastructure, lack of participation of farmers in development programmes, lack of trained extension personnel, lack of market information on demand and supply of produce and extensive support are still serious challenges in Limpopo province. This is based on the fact that the majority of these farmers do not have collateral.

3.10 Socio economic situation context in Limpopo province

Limpopo province is one of the poorest provinces of South Africa; it is ranked last in terms of human development index (StatsSA, 2011). As mentioned earlier Limpopo Province is in the North East of South Africa and covers an area of 123, 910 square kilometers, 10. 2 percent of the area of South Africa. The province shares borders with Botswana, Zimbabwe and Mozambique.

Table 3.1: A comparison of social indicators for South Africa and Limpopo province

Indicators	South Africa	Limpopo
Population (Census 2001 , published 2003)	50.5 million	5.5 million
Population growth rate	2.2%	2.31%
Urban population as percentage of total	61%	20.95%
Infant mortality rate	44.8	53
Total fertility rate	2.5	2.85
Percentage of population <15 years	34.33%	42.75%
Life expectancy at birth - males	52.1	55.8
Life expectancy at birth - females	56.2	61.4
Total unemployment rate	23.9%	19.3%
Doctors per 10 000 population	2.9	1.5
Hospital beds per 1 000 population	4.0	3.1
<i>Diseases</i>	22.8%	11.5%
Percentage of HIV – infected women at antenatal clinics	-	286
Malaria cases per 10 000 population	22 950	4 814
Tuberculosis cases per 100 000 population	63 136	1 947
Typhoid cases per 100 000 population	425	98
Viral hepatitis cases per 100 000 population	1 042	109
Human Development Index	0.61	0.52
Gini coefficient (income)	0.679	0.690
<i>Infrastructure:</i>		
Percentage of households with access to electricity for lightning	81.2	80
Percentage of households with access to electricity for cooking	66.5	40.3
Percentage of households with access to piped water	88.6	83.6
Percentage of households with access to flush toilet	60.4	20.2
Percentage of households with access to pit latrine with ventilation	6.8	10.5
Percentage of households with access to pit latrine without ventilation	21.5	56.3
Percentage of households with bucket toilet system	2.3	0.1

Source: UNHDR (2011); StatsSA (2007); StatsSA (2011); DBSA (2011)

3.10.1 Basic social indicators

Table 3.1 gives a good indication view of the basic social indicators of Limpopo and South Africa as a whole for comparison. According to StatsSA (2006), Limpopo Province is the fourth-most populated province, after Kwazulu-Natal, Gauteng and Eastern Cape. Limpopo Province is at the lower end of the socio-economic spectrum in South Africa and ranks among the bottom three regions in terms of its socio-economic position (StatsSA, 2011). Large numbers of people, however, living in the rural areas in the former homeland states are still affected by poverty and illiteracy. Limpopo Province is no different. Other activities such as tourism and mining are, fortunately, playing vital roles in the growth of job opportunities in the province.

The population of the province is estimated at 5.5 million of which 54.6 percent is women, 45.4 percent is men, youth at 39.4 percent (StatsSA, 2011). Unemployment in the Province is quite high, estimated to be between 36 percent and 68 percent differing in the 5 districts and 25 local municipalities (NDA, 2009). In the 2001 census, 33.4 percent of the population older than 20 years had no schooling, 49 percent of the economic active age group (15-64 years) was unemployed and 61 percent of the population lived below the 2002 national poverty line. The population of Limpopo province increased from 4.9 million in 1996 to 5.2 million (11 percent of the population of South Africa) in 2001 (StatsSA, 2006). The peoples' ability to live long and healthy life, and also to communicate and to have sufficient means to afford decent living is nearly low as seen in Table 3.1 , where Limpopo Province Human Development Index is at 0.52. The province also has high level of inequality, with Gini coefficient at 0.69 as shown in Table 3.1.

The age distribution of the population in Limpopo resembles the typical broad-base pyramid of developing countries, with a large portion of the population in the younger age groups and a steadily decreasing proportion in the older age groups. This implies a unique educational, recreational and developmental interventions challenge, but also offers an opportunity for growth. Another distinctive feature of the province is that Limpopo has the highest female/male ratio in the country (StatsSA, 2006). Females account for 54, 7 percent of the population in the province while the national average is 52.2 percent (NDA, 2009).

Table 3.2: Population distribution by municipality – Community survey 2007

Municipality	Population
<i>Capricorn</i>	
Blouberg Local Municipality	194119
Aganang Local Municipality	145454
Molemole Local Municipality	100408
Polokwane Local Municipality	561772
Lepelle – Nkumpi Local Municipality	241414
Total	1243167
<i>Greater Sekhukhune</i>	
Makhuduthamaga Local Municipality	262726
Fetakgomo Local Municipality	112232
Ephraim Mogale Local Municipality	124510
Elias Motsoaledi Local Municipality	247488
Greater Tubatse Local Municipality	343468
Total	1090424

Source: StatsSA (2011)

Capricorn District municipality is situated in the centre of Limpopo province, sharing its borders with other four district municipality namely; Mopani, Sekhukhune, Vhembe and Waterberg. The district is situated at the core of economic development in the Limpopo Province and includes the capital of the province, that is, the City of Polokwane. According to StatsSA (2011), the total population of Capricorn district is estimated at 1 243 167 as shown in Table 3.2. A total of 285 656 households live in the district municipal area and average household size is 6.1 persons. Population is predominantly female and children with large number of single female-headed households concentrated in rural areas, living in poor conditions and poverty. More than 40 percent of the district population lives in Polokwane and is the most densely populated while Blouberg area is least densely populated.

The Greater Sekhukhune district municipality is situated in the North West of Mpumalanga and the south of Limpopo making it a cross border municipality. It is located outside major towns such as Pretoria at approximately 200km to the south. The total population of the district is at 1 090 424 as shown in Table 3.2, with 217 000 households living in municipal areas. Half the population is below 18 years and the male, female ratio at this age is equal whilst the female population is over 60 percent over the age of 18 or working age (StatsSA, 2007).

3.10.2 Demographic and economic indicators in South Africa

a) Employment

The employment challenge has been the focus of concerted deliberations by government, business, labour and community representatives. Two major characteristics of unemployment in Limpopo province is the pronounced unemployment rate in rural areas due to the lack of industries, other viable employment opportunities in these areas and lack of capital markets, which makes it impossible for rural households to improve their livelihoods (DBSA, 1998; South African Year Book, 1999; Kunfaa *et al.*, 2002; Mpandeli, 2006; StatsSA, 2011).

Table 3.3: Unemployment rate in Limpopo Province as compared to other Provinces in South Africa

Province	Unemployment rate
Eastern Cape	26.9
Free State	27.9
Gauteng	26.9
Kwazulu Natal	20.3
Limpopo Province	19.3
Northern Cape	31.3
Mpumalanga	30.8
North West	25
Western Cape	22.2

Source: StatsSA (2011)

Unemployment is a major problem in most developing countries. The highest estimates of unemployment mostly come from rural areas (Kunfaa *et al.*, 2002). In South Africa, the

province recording the highest unemployment rate is Northern Cape with 31.3 percent. As indicated in Table 3.3, Limpopo Province has the lowest unemployment rate at 19.3 percent followed by Kwazulu Natal with 20.3 percent (StatsSA, 2011). South Africa unemployment rate is at 23.9 percent as seen in Table 3.1.

Table 3.4: Important demographic and selected economic characteristics in Limpopo province

Characteristics	Limpopo
Population size	5.5 million
Male	2 578 344
Females	2 976 313
Urban	10.9%
Non – urban	89.1%
Urban males	12.4%
Non urban males	87.6%
Urban females	11.4%
Non urban females	88.6%
Most important source of income (%)	
Wages	43.1%
Pension	27.1%
Remittances	21.5%
Farming	2.2%
Other	6.1%
Household income in the month prior to survey (%)	
R1501 or more	10.1%
R801 – R1500	20.6%
R401 – R800	33.1%
R400 or less	36.2%

Source: StatsSA (2011)

Limpopo province's economy currently contributes the fourth least to the South African Gross Domestic Product (GDP) and labour absorption, ahead of Free State and Northern Cape and North West (StatsSA, 2011). Its capacity as a major market for goods is constrained by unemployment and lack of income. While the rural unemployment rate for South Africa was around 44.2 percent (urban = 28.6 percent) in 1996, the unemployment rate in Limpopo province was 50.5 percent (23.7 percent in urban areas) in 1996, which translate to over 487 000 of economically active people in 1996. Unemployment in

Limpopo declined to 43.5 percent in 2002 but rose again to 49.3 percent in 2003 and thus is now at 19.3 percent (StatsSA, 2011). 43 percent of Limpopo province people receives income from their wages and 27.1 percent from pension as indicated in table 3.4. 36.2 percent falls under 400 or less monthly income category while only 10.1 percent falls under 1501 or more household income category. Against this background, the demographic and selected economic indicators in Limpopo are summarised and presented in Table 3.4. In any country the youth are considered to be the future, however, they have to be skilled, mentored and groomed to take part in growing the economy. Unfortunately, the South African youth unemployment makes up 48.5 percent of total unemployment in Limpopo province. The census confirmed the unemployment burden falls on black men and women under the age of 35 and is particularly severe in rural areas (Rwelamira, 2008).

Table 3.5: Statistical information on employment and unemployment levels in Sekhukhune District – Community survey, 2007

Description	Ephraim Mogale	Tubatse	Fetakgomo	Elias Motsoaledi	Makhudu Thamaga
Employed	15056	45321	7236	38098	21978
Unemployed	11098	51551	11566	16725	33346
Non economically active	40787	90696	39511	79066	77494
N/A	20 031	110 467	43 390	42 472	126 622
Unspecified	40	-	-	-	-
Total	87012	298035	101703	176361	259440

Source: StatsSA (2011)

According to Table 3.5 unemployment is decreasing for Sekhukhune District as compared to previous years as a results of government public works programmes which employed lot of people in the district, currently 124286 people are not employed, which is around 15 percent of the population far less than the provincial 19.3 percent. Of those employed, 91.5 percent are in informal sector while 8.5 percent is engaged in the formal sector (StatsSA, 2006). According to StatsSA (2011) about 127689 people are employed. Makhuduthamaga, Fetakgomo and Tubatse scoring above the district average. The economy of Sekhukhune needs to create 2800

jobs per year in order to reduce the unemployment rate by 1 percent per year (StatsSA, 2011).

Table 3.6: Statistical information on employment and unemployment levels in Capricorn District - Community survey (2007)

Description	Aganang	Blouberg	Lepelle Nkumpi	Molemole	Polokwane
Employed	14458	10420	22001	17851	161577
Unemployed	12712	11579	20025	8561	36750
Non economically active	44261	57682	1812	26185	-
N/A	-	-	-	1303	-
Unspecified	-	-	3657	-	-
Total	71431	79681	47495	53900	198327

Source: StatsSA (2011) ; Quantec Research (2008)

In Capricorn District, a significant number of economically active people are working in other districts and provinces such as Gauteng to earn income and return home to their families over weekends or month ends. This means a significant proportion of the population is dependent on the income generated by others as seen in Table 3.6, especially the percentage of those people who are not economically active. While the unemployment rate of 18 percent for the district is lower than the national average of 25 percent, the employment rate is also lower at 26.9 percent as compared to none economically active population at 52.3 percent.

b) Poverty rates in Limpopo province

Two thirds of the province's population live in poverty, while 40 percent live in 'ultra-poverty', defined as people living on incomes of less than R2 717 per year. The poverty rate of Limpopo Province is at 64.6 percent (StatsSA, 2006). There was also a major difference in the poverty rate according to gender: 45 percent of all female-headed households lived below the "lower-bound" poverty line, compared to only 25 percent of male-headed households (Armstrong *et al.*, 2009; Mpandeli, 2006). Living conditions and access to services are areas in which considerable disparities also exist

- the lack of access to services experienced by the poor often contributes to the difficulty entailed in moving out of a state of poverty. A large proportion of the poorest households continue to live in informal and traditional dwellings.

The Capricorn District has one of the highest poverty rates in the country at 61 percent (StatsSA, 2006). This means that 61 percent of households in the district have a monthly income below R800. This high level of poverty is due to various factors like lack of education, skills, qualification ect. Capricorn population is 97 percent African, 2 percent white and 1 percent Indian (Rwelamira, 2008). The African population has historically been impoverished, and this has not changed significantly over the past 15 years. Some 38 percent of the total population is between the ages of zero and 14. This indicates a high level of dependency considering the poverty level in households in the district. The fact that 22 percent of the population in the district receive child support grants indicates high level of dependency.

In 2001, Sekhukhune district was declared one of the 13 nodal areas in South Africa that need accelerated development. These are areas with extreme poverty, serious lack of skill and service. The Sekhukhune district has a very high poverty level, 84 percent of the people are defined as poor (having less than R1500 per household per month) and 66 percent defined as very poor (having less than R550 per month) (DWAF, 2005).

There is also a limited access to assets particularly land, capital in Sekhukhune which improve economic and social security. This will in turn provide the basis for economic engagement in the longer. According to Makhura *et al.*, (2000) the major cause of poverty in Sekhukhune district is lack of earned income due to high unemployment level and low levels of education in the area. This will require a direct intervention in the provision of resources to those affected areas and promoting effective and efficient delivery of public service.

c) Income distribution and inequality in the Limpopo province

The biggest single issue facing Limpopo province is poverty. In the Limpopo province, the inequality and contrast between rich and poor is starker than in other provinces despite

potential for economic growth (Landman, 2005; Mpandeli, 2006). In addition the distribution of income and wealth in Limpopo province is among the most unequal in the South Africa, and many households still have unsatisfactory access to education, health care, energy and clean water (Landman, 2005; Mpandeli, 2006). This situation is also supported by the former president Thabo Mbeki when he famously argued that “Material conditions ...have divided our country into two nations, the one black, and the other white. ...[the latter] is relatively prosperous and has ready access to a developed economic, physical, educational, communication and other infrastructure...The second, and larger, nation of South Africa is black and poor, with the worst affected being women in the rural areas, the black rural population in general and the disabled” (Mbeki, 1998).

It is very clear that households in Limpopo province lives under conditions of grossly underdeveloped economic, physical, educational, communication and other infrastructure. It has virtually no possibility to exercise what in reality amounts to a theoretical right to equal opportunity. This will turn make it difficult for households to adapt under difficult conditions like economic downturn , climate change , HIV AIDS , swine flu and etc (Oni *et al.*, 2003 ; Mpandeli, 2006).

d) *Education status in the Limpopo province*

According to the Department of Education (2002) the adult literacy rate in the province was 59 percent in 2000. There are approximately 1.8 million learners in Limpopo of which 1.4 percent (24877) attends farm schools (DoE, 2002). Most schools do not have access to basic services in the province (90 percent have access to toilet facilities, 60 percent to water and 50 percent to electricity). Limpopo province spent approximately R3 720 per learner/year in the province (DoE, 2002). Transportation of learners is a big problem especially rural areas. In many areas there are no other means of transport except for learners to walk great distances to school, which impacts on their ability to learn.

Table 3.7: Education profile of Sekhukhune District Municipality- Community survey (2007)

Description	Ephraim Mogale	Tubatse	Fetakgomo	Elias Motsoaledi	Makhudu Thamaga
No Schooling	2079	13326	1897	5142	12085
Primary Education	4968	36167	3805	16854	19415
Secondary Education	4607	38881	3906	18883	20414
Certificate/Diploma	1410	3366	427	1411	1498
Degree/ Higher	149	653	90	519	472
Unspecified	75	1683	56	1138	1471
Total	13288	94076	10181	42536	53857

Source: StatsSA (2011)

According to Aird and Archer (2004) there is a considerable number of people in the district with little or no education. The district has a relatively high illiteracy level, with almost 28 percent of the population having no formal school education. Only around 1 percent of the population has obtained educational requirements.

There is however a strong generational differentiation in terms of level of education with many of the older generation not having had any schooling while young generation have a much higher school attendance rate. According to DWAF (2005) school facilities are not adequate in many areas with 335 schools out of a total 737 schools in the district not having acceptable levels of water availability. The low skill in Sekhukhune is hampering the ability of the district to be innovative and economically productive as shown in Table 3.7 where only a small portion of population has degree/ higher qualifications as compared to majority with no schooling and primary education.

Table 3.8: Education profile of Capricorn District Municipality- Community survey (2007)

Description	Aganang	Blouberg	Lepelle Nkumpi	Molemole	Polokwane
No Schooling	15636	32833	31384	13650	36515
Primary Education	53018	19025	74838	32920	202237
Secondary Education	59273	23638	72424	35625	267150
Certificate/Diploma	3372	3048	8660	3411	23032
Degree/ Higher	165	229	655	904	32021
Unspecified	-	-	-		-
Total	131464	78773	187961	86510	560955

Source: StatsSA (2011)

According to CDM (2011) 15 percent of Capricorn population (over 15 years) did not have schooling; while 19 percent have completed matric and 8.2 percent have post matric qualification. This situation is also supported by StatsSA (2011) which highlighted that only a small portion of the population has degree/ higher qualification as shown in table 3.8. The majority of Capricorn population falls under no schooling and primary education category as shown in Table 3.8. The lack of and in some instances total absence of access to water, sewage, electricity and telecommunications remain a challenge. There is also a general absence of school based entrepreneurship programmes, which are essential in moulding an entrepreneurial culture in a society that is highly affected by unemployment. There are about 11 public tertiary institutions in Capricorn district. The major of these tertiary institutions in the district include the University of Limpopo (Mankweng campus), University of South Africa and Tshwane University of Technology.

3.11 Health and welfare issues in Sekhukhune District

There are number of hospitals and clinics spread around Sekhukhune district but resources at these health centers and accessibility remains poor (GSDM, 2007). The district has one provincial hospital, 6 community hospitals, 72 clinics and 19 mobile clinics (GSDM, 2007). These clinics and hospitals are evenly distributed throughout the district, but the

accessibility of these to the people remains a challenge. At the moment the rural areas are still the most disadvantaged in terms to access to hospitals (Makhura, 2001). Again Makhura (2001) emphasize that the transport cost to these clinics and hospitals are very high or unaffordable to many people due to high poverty levels. According to GSDM (2005) there are chronically low levels of professional availability (medical officers, pharmacists, professional and staff nurses) in both hospitals and clinics due to the facts that the majority of these professionals prefer to work in Polokwane or urban areas.

About 13 clinics did not have sanitation at an acceptable level, many only having the use of pit latrines (DWAF, 2005). In clinics where the water problem is particularly severe, clinics is required to bring water in tankers. Only 7.8 percent of the population has access to medical aid scheme (GSDM, 2007). Again due to poor access to clean water and sanitation Sekhukhune is at a higher risk of contracting opportunistic infections like diarrhoea, worms and bilharzias. It is estimated that 78 percent of rural villages in Sekhukhune do not have access to basic Reconstruction and Development Programme level sanitation and this constitutes a large threat in terms of the contamination of ground water (WSDP, 2008). In addition, a slight majority of Sekhukhune schools (53 percent) receive below RDP standard sanitation service, which is a better picture than the households.

According to Zanner *et al.*, (2004) the most common health problems in Sekhukhune district include hypertension, diabetes, tuberculosis and asthma. HIV / AIDS is of great concern for the country as a whole and Sekhukhune district is no exception. The rate of HIV AIDS infection in Sekhukhune is at 13.4 percent. Due to inadequate access to water and sanitation in Sekhukhune it is difficult for people living with HIV to cope. About 7 percent of the populations have no means of sanitation. The worst group hit by the virus is the young adult population, particularly between the ages of 20 and 30 years (Aird and Archer 2004).

3.12 Health and welfare issues in Capricorn District

According to CDM (2011), Capricorn district has 2 provincial hospital, 6 community hospitals, 88 clinics, 31 mobile clinics and 1 private hospital. Again in Capricorn access to these health facilities remains a challenge to the people due to poverty levels. Only 5.9

percent of the population has access to a medical aid scheme (CDM, 2011). HIV AIDS prevalence appears to be declining, based on both the antenatal survey and routine data (CDM, 2011). The HIV testing rate of pregnant mothers has improved to 82.5 percent in 2007/08. The nevirapine uptake rate of HIV positive mothers improved to 64.6 percent but there are problems with data regarding nevirapine uptake in newborns. However, more attention still needs to be given to monitoring of this HIV prevention programme.

Capricorn district municipality accounts for 16.5 percent of the provincial RDP sanitation backlog, with Polokwane local municipality at 43.6 percent backlog. According to CDM (2005) has the lowest RDP sanitation service levels in the district; 78.4 percent of the households have access to sanitation. The other municipalities in Capricorn have acceptable RDP sanitation service levels as greater than 90 percent of the households have access to sanitation. But there are some challenging issues regarding sanitation across the district. A total of 186 919 (69 percent) of households are below RDP standard for sanitation. Some households still use pit latrines, buckets latrines and some have no sanitation.

3.13 Biophysical factors in Sekhukhune District

3.13.1 Climate

Sekhukhune is blessed with a climate which is ideal for agricultural activities. Agriculture is one of the core business in the district and generates a lot of the areas annual income (GSDM, 2007). It is not without reason that Sekhukhune is part of the “Sunshine Valley”. The summer months in Sekhukhune starts at late August and ends late April. In fact, Sekhukhune only have 3 months of real winter weather.

Sekhukhune is any Landscape Artist’s dream. The natural vegetation is bushveld with tropical and sub-tropical vegetation growing in a lot of gardens. January is one of the warmest months during summer, the maximum temperatures can go as high as 38°C. During July, which in turn is one of the coldest months of winter, the temperature can drop to a minimum of 7°C and a maximum of 28.2°C. The average annual rainfall is $\pm 559\text{mm}$ (GSDM, 2007).

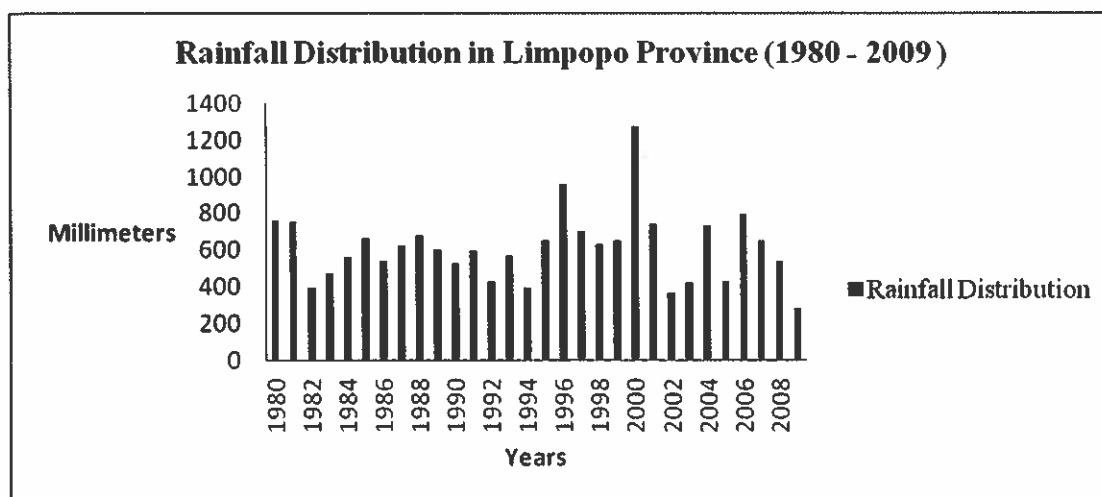
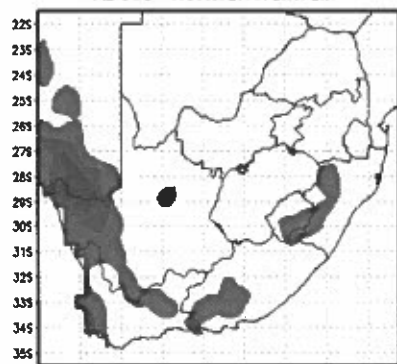


Figure 3.1: Rainfall Distribution in Limpopo province (1980 – 2009)

Source: SAWS (2012)

As indicated in figure 3.1, there is variation in rainfall distribution in Limpopo province overtime. According to LDA (2010) Limpopo province average annual rainfall is 600mm and the threshold for rainfall agriculture is averaged at 250mm annually. It is evident from figure 3.1 that there was a shortage of rainfall in the following years: 1982 , 1983, 1984, 1986, 1990 , 1991, 1992 , 1993 , 1994 , 2002 , 2003 , 2005 , 2008 , 2009 respectively. According to Letsatsi –Duba (2009) the occurrence of drought in 2009 was the worst ever in Limpopo province. This is also evident in figure 3.1 which shows rainfall averaged to 282,1mm annually in 2009, nearly dropping below threshold for rainfall agriculture. There were also good rainfall years in Limpopo province as shown in figure 3.1 especially 1980, 1981, 2000 and 2001 respectively. In general it can be concluded that rainfall distribution has indeed changed in the past 30 years in Limpopo province and information on rainfall amount and climate variability is important for improved decisions making with regards to planting time,-crops choice and crop variety etc. As a result of the rainfall fluctuations over the past 30 years, it is important for farmers in the province to adopt multi cropping system in order to counteract the problem of rainfall distribution across the districts. The rainfall that Limpopo province had in 2000 caused lot of damages on crops, livestock, infrastructure (Mpandeli, 2006). In some areas people lost their lives due to floods, outbreaks of cholera etc as seen in figure 3.1.

May – July: Above Normal Rainfall



May – July: Below Normal Rainfall

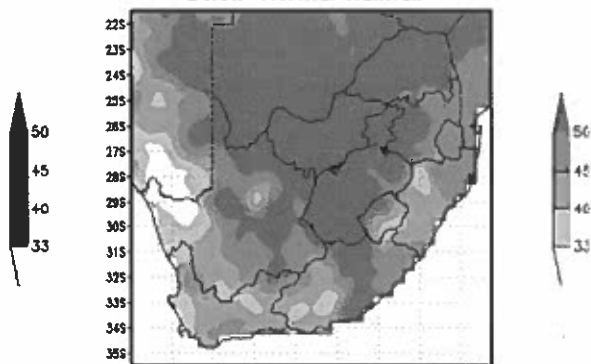
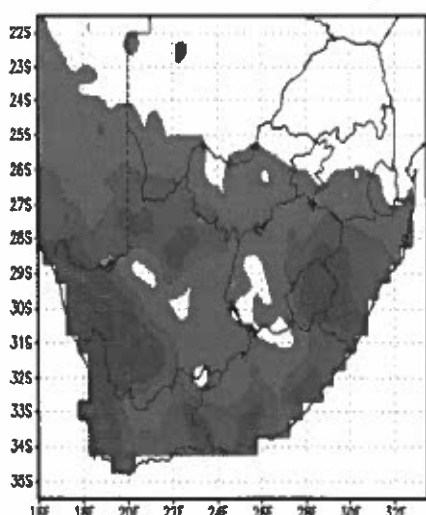


Figure 3.2: Rainfall Outlook in Limpopo province: May – July 2012
Source: SAWS (2012)

As indicated in figure 3.2 the rainfall outlook for Sekhukhune and Capricorn districts looks very poor. The results indicated that the probability of both districts in receiving below normal rainfall is 50 percent for May – July 2012. It is evident from figure 2.2 that there is no / little probability for both districts to receive above normal rainfall. This will create lot of problems for farmers and it will require the use of adaptation measures like using of drip irrigation which saves water, irrigating during cool conditions to avoid evapotranspiration and to adhere to the water restrictions issued all the time.

July – September: Above Normal Rainfall



July – September: Below Normal Rainfall

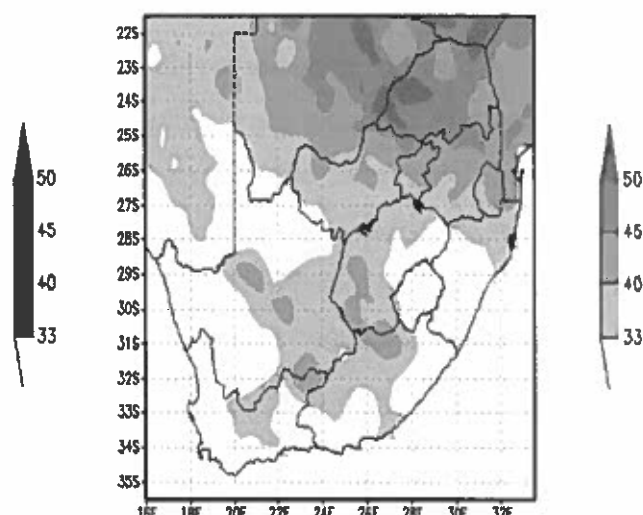


Figure 3.3: Rainfall Outlook in Limpopo province: July – September 2012
Source: SAWS (2012)

The situation in Sekhukhune and Capricorn districts improves towards August as reflected in figure 3.3, with 45 – 50 percent probability of below – normal rainfall expected towards August. The results also show improvement in above normal rainfall probabilities in both districts at 33 – 40 percent. This current situation shows change in rainfall patterns in Limpopo Province occurring throughout the year and it emphasise the need for farmers to be vigilant to adapt to changing weather patterns.

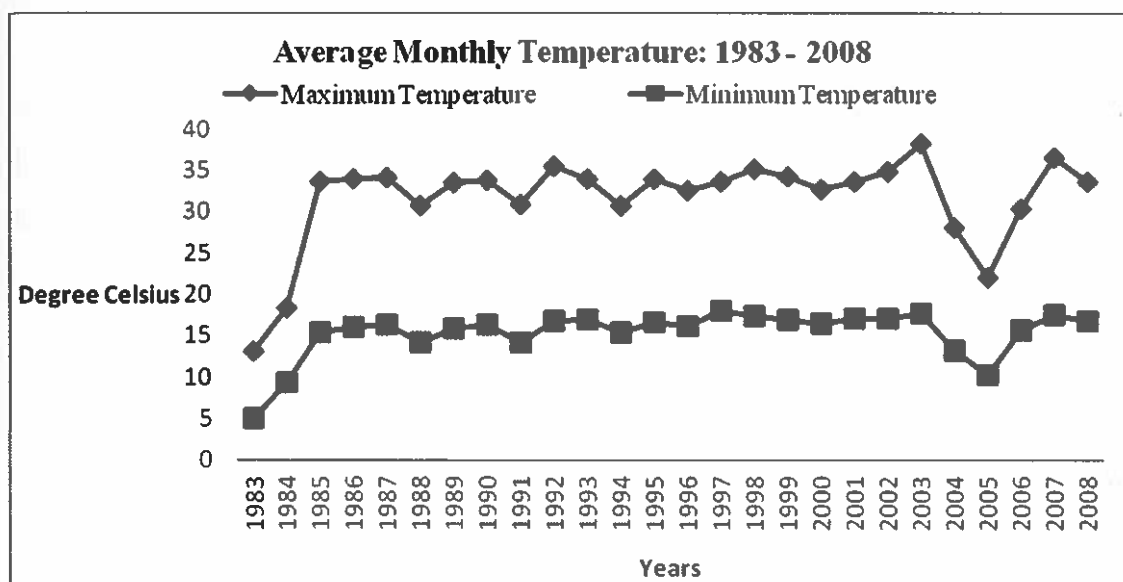


Figure 3.4: Sekhukhune District Monthly Average Temperature - 1983 – 2008

Source: SAWS (2012)

According to Climate Info (2012) average minimum monthly temperature in South Africa is at 13.8 degrees Celsius and average maximum monthly temperature is 26 degrees Celsius. As indicated in figure 3.4, Sekhukhune district temperature has been changing overtime and showed high temperature levels which are above South Africa average. These results are consistent with Hugues and Balling (1996) who reported that there is an increase in average temperatures per decade over the period 1960 – 1990 and these trends were significant for both non urban and urban stations. Figure 3.4 shows that only average temperatures in 1982, 1983, 2004 and 2005 were below the South Africa average temperature. This result also explains why Sekhukhune district is frequented by droughts and poor rainfall.

3.13.2 Topography

The Olifants River is located on an open floodplain area. A valley surrounded by the non perennial rivers is found to the north of the river. Strips of erosion can be found in the valley alongside most of the perennial and non-perennial rivers. Wood is still one of the main sources of energy for households, which leads to deforestation and subsequent erosion because of the denuding vegetation. One of the major environmental problems in the area is inappropriate agricultural methods, which leads to overgrazing. Overgrazing is also the result of too many livestock units per area of land (GSDM, 2007).

3.13.3 Soils

A wide range of soils occur in Sekhukhune District, ranging from deep to moderately deep red sandy loams (usually coarse grained, and rarely medium) to heavier soils on slopes. On dip slopes, *Combretum apiculatum* or *Diplorhynchus condylocarpon* are dominant. Scarp slopes and pediments are occupied by *Kirkia wilmsii*, *Acacia nigrescens* and *Commiphora* spp., while *Catha transvaalensis*, *Combretum molle* and *Vitex* spp. are typical (ARC – ISCW, 2011).

3.13.4 Geology

The regional geology consists of the Eastern Bushveld and Springbok flats regions. According Goode (2006) the overall geology of the area is classified as follows:

- Gabbro (South of the R37)
- Anorite band (adjacent to the R37)
- Clinopyroxenite (to the North of R37)
- Arenite (adjacent to the Olifants river)

The Springbok flats coal fields are found on the western side of the Sekhukhune District. The Transvaal Supergroup is found in Marble Hall towards the east of the District, as well

as in anarc inscribed by the Northern Drakensberg in the far east. The stones and rocks found within the Transvaal Super group include dolomite, limestone, iron-formation, shale and quartzite, amongst others (GSDM, 2007).

As mentioned earlier, the unique geology of Sekhukhune has bequeathed the District with the largest reserves of platinum group metals in the world. The renowned Bushveld Complex is found at the centre of the region. The western portion contains acidic rocks, whilst the eastern site has basic rocks which contain metal minerals. It is the latter that is of economic significance. The Merensky Reef is found within this Complex, and contains major deposits of the platinum group metals, nickel, copper and cobalt (GSDM, 2007).

3.13.5 Air quality

Sekhukhune district has few sources of air pollution, owing to the fact that the communities are largely rural, with few industries and few motor vehicles on the roads. Key air quality issues in the district are open fires and dust from roads. Odour is also an issue in informal settlements, where unpleasant odours originate from pit latrines and illegal dumping of waste (GSDM, 2007).

3.13.6 Water

The climate in Sekhukhune district is highly variable in terms of rainfall intensity, duration and frequency. Many people in Sekhukhune views this as a source of limited amount of water available rather than directly specifying climate as a stressor (Ziervogel *et al.*, 2006). According to DWAF (2005) many households in Sekhukhune district are extracting water from rivers, springs and wells and this creates increased levels of risks to diseases, particularly cholera, bilharzias and diarrhoea. It is confirmed that almost 33 percent of the population depends on natural water supply as a source.

Furthermore, 46.9 percent of the population is receiving below basic RDP level water services (GSDM, 2007). The district held a water summit in 2005 to address the massive backlogs that the district is experiencing. At present Department of Water Affairs has allocated a budget to raise the Flag Boshielo dam walls and to construct a new dam (De

Hoop dam) in order to increase the capacity of the district to provide water to the communities. Given the state of water resource in Sekhukhune, these two dams will definitely improve the state of water provision in the district, and this will eventually boost tourism and other developmental opportunities

3.14 Biophysical factors in Capricorn District

3.14.1 Climate

The northern part of Capricorn is arid (Rainfall = 300 to 400 mm/a) and the southern part is semi-arid (Rainfall = 400 to 500 mm/a). Summer rains commence in Oct / Nov and end in April and peak in December. Annual droughts occur regularly. Annual rates of evaporation throughout Capricorn are high, and in all areas exceed mean annual precipitation. This results in a semi-arid landscape with limited availability of surface water resources e.g. perennial springs, streams and small dams. Mean annual evaporation in Capricorn is between 1700 and 1800 mm per year (CDM, 2011)

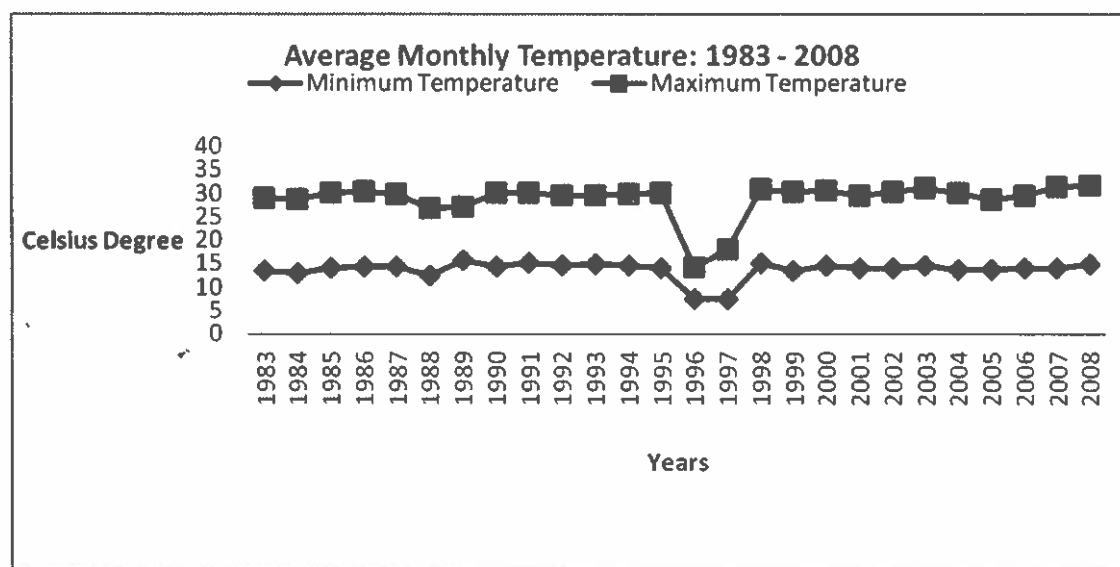
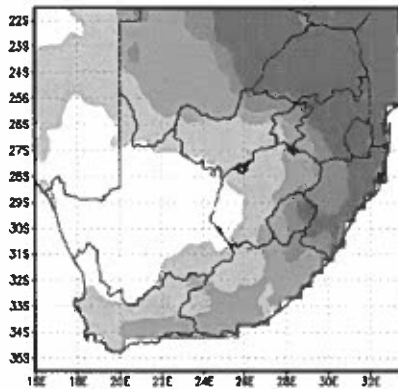


Figure 3.5: Capricorn District Monthly Average Temperature - 1983 – 2008

Source: SAWS (2012)

Capricorn district average temperatures trends shows high levels which are above South Africa average temperatures. Only few years namely 1988, 1996 and 1997 shows average temperatures that are below South Africa average temperatures as indicated in figure 3.5. This situation is also supported by Kruger and Shongwe (2004) who found that there was a significant increase in temperature between 1960 – 2003 for Polokwane, Bela Bela and Musina stations in the Limpopo province. This condition has lead to occurrence of droughts around Capricorn district and put most farmers vulnerable due to climate variability and change.

June – August: Above Normal Temperature



June – August: Below Normal Temperature

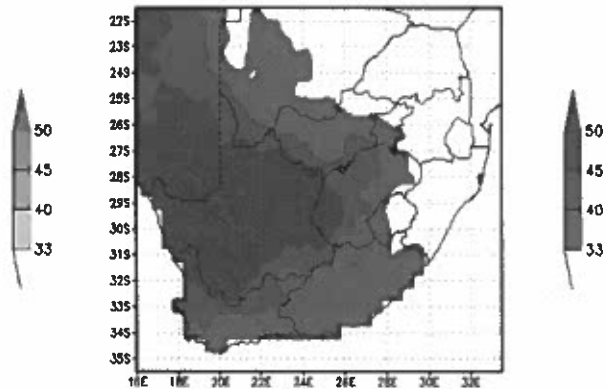


Figure 3.6: Temperature Outlook in Limpopo province: June – August 2012
Source: SAWS (2012)

The results in figure 3.6 shows that average temperatures in Sekhukhune and Capricorn districts for June – August 2012 is high. The results showed enhanced probabilities of 50 percent for above normal maximum temperatures in the entire Limpopo province. This is again raising a very serious temperature trends in Limpopo province which will increase poor rainfall patterns and accelerate frequency of droughts.

3.14.2 Topography

Capricorn district consist of 200 – 800 flat plains of the lowveld which accounts to 92 percent of the district. There is also 80 – 1200 undulating Highveld, which account to 7 percent of the district. Capricorn district has also > 1200 mountainous region, which account to 1 percent of the district (CDM, 2011).

3.14.3 Soils

The soils of the Capricorn district area are generally red-yellow pedal, freely drained soils; red, high base status, more than 300 mm deep (ARC-ISCW, 2011). Scattered and relatively small areas of high agricultural potential soils occur around the district. Some municipal areas consist of soils with moderate and low potential soils for agricultural activities (CDM, 2011).

3.14.4 Geology

In the Capricorn district there are arenites of the Matlabas Subgroup of the Waterberg formation (Barker *et al.*, 2006). The Waterberg rests unconformably on rocks of the Transvaal Supergroup, granites and mafic rocks of the Bushveld Igneous Complex and Archean gneisses and granites of the Kaapvaal Craton. Rocks of the Karoo Supergroup are also available. Centrally, severely faulted rocks of the Soutpansberg Group are found. This group comprises a volcanic and sedimentary rock succession, the strata of which gently dip in a north-northwest direction (Barker *et al.*, 2006). Copper mineralisation has been known to be found in the Soutpansberg Group of rocks. There are also varieties of gneiss and meta sediments of the central zone of the Limpopo belt.

3.14.5 Air quality

Capricorn district has few sources of air pollution, owing to the fact that the communities are largely rural, with few industries and few motor vehicles on the roads. Key air quality issues in the district are open fires and dust from roads. Odour is also an issue in informal settlements, where unpleasant odours originate from pit latrines and illegal dumping of waste (CDM, 2011)

3.14.6 Water

The scarcity of natural resources, a pre condition for rolling out waterborne sanitation in Capricorn district is a critical issue. According to Monakedi (2009) no new bulk water resources will be available before 2011 to many parts of the district. At present new developments in the district rely on the use of ground water sources, which in some area is not sustainable. It was further emphasised by Makunyane (2009) that it has been established that close to 70 percent of water resources in the district are used for agricultural purpose. Furthermore, some large employers have raised concerns about disruption of water supply and some have even threatened to relocate to other parts of the country like Free State where disruptions are minimal. This unbecoming situation creates the condition for competition for water resources between sectors of economy and domestic use.

Climatically the Capricorn district is classified as semi – arid. It should also be noted that there are no major river systems flowing through the district and already water has to be imported. The entire district is water scarce as it does not have many primary sources of water. The drying out of boreholes, stolen engines and the turnaround periods for operation and maintenance is affecting the provision of adequate and sustainability of water supply within Capricorn district. Since most water in the district has to be sourced from across hydrological boundaries outside, the continued use of water and the need in future for irrigation water may not be sustained over a long period in Capricorn district.

3.15 Summary

- 1) The Limpopo Province is one of the poorest province in the country, characterized by high unemployment rate, poverty and lack of access to a range of resources that frustrate majority of people ability to secure their livelihoods. In this chapter the province economic, biological and physical environments were highlighted. It further covers the province farming enterprises, farming systems, farm categories, infrastructure and some of the constraints that are facing emerging farmers in the province.
- 2) Some of the socio economic issues were also addressed in this chapter like including population, gender, age, poverty, employment, income distribution, inequality and the

province education. Important issues on poverty levels in the study areas, health, water, and sanitation and water resources were also discussed to give an overview of study areas situation.

- 3) The employment challenge has been the focus of concerted deliberations by government, business, labour and community representatives. Two major characteristics of unemployment in Limpopo province is the pronounced unemployment rate in rural areas due to the lack of industries, other viable employment opportunities in these areas and lack of capital markets, which makes it impossible for rural households to improve their livelihoods.

CHAPTER 4

Measuring the impact of climate variability and change on agricultural production in Limpopo province

4.1 Introduction

Several international and local concerns around climate variability and change in Africa focus on adaptation and vulnerability to climate (WCED, 1987; IPCC, 2001; Brown *et al.*, 2002; Mpandeli, 2006). Extreme weather events in Limpopo province disrupts cropping programmes, reduce stock and threaten the resource base of farming enterprise. The majority of people in Limpopo province are also affected by poverty, high unemployment rate and recurrent change in weather patterns (UNDP, 2004; NEPAD, 2001; FAO, 1998; Mpandeli, 2006). Most parts of Limpopo province were affected by flooding, high temperatures, drought in the past five years and lately in Sekhukhune and Capricorn districts.

Agricultural sector is vulnerable to climate variability and change physically and economically. Due to climate change, agricultural supply will be affected, especially relative prices of agricultural commodities and consequently reallocation of resources within the agricultural sector, altering the structure of the economies of numerous countries and the international trade pattern (Deke *et al.*, 2001). It is therefore important to understand the ways in which agricultural sector operates and how farmers cope and adapt to climate variability and change in Limpopo province.

4.2 Characteristics of sample

As mentioned earlier in chapter 1, a representative sample of 300 farmers was selected. It was noted that 46 percent males and 54 percent females participated in the study. The study involved Sekhukhune and Capricorn districts (Table 4.1), with 56 percent farmers in Capricorn and 44 percent in Sekhukhune district.

Table 4.1: Summary characteristics of sample in 10 local municipalities.

Variable	Total	Percentage
Number of Farmers per District		
Capricorn	167	56
Sekhukhune	133	44
Number of Farmers per Local Municipality		
Aganang	26	8.7
Blouberg	16	5
Polokwane	31	10
Lepelle Nkumpi	51	17
Molemole	43	14.3
Greater Tubatse	22	7
Makhuduthamanga	20	6.7
Fetakgomo	31	10.3
Ephraim Mogale	52	19
Elias Motsoaledi	8	2.3
Sex of Farmers		
Male	136	46
Female	164	54
Total	300	100

The following 10 local municipalities were visited: *Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane, and Molemole* (Table 4.1). The selection of the districts were based on different agricultural setups and different agro - climatic zones or conditions. The purposeful sampling method used covered most of the productive farms in the two selected districts in the province and also covered the uniform or homogeneous characteristics of farmers. The sample frame was designed to meet the objectives of the study and it had to adhere to the statistical specifications for accuracy and representativity.



Picture 4.1: Questionnaire used both in Capricorn and Sekhukhune Districts

The survey was conducted in July – September 2011 on purposefully selected farms using questionnaire (see picture 4.1). Each local municipality provided agricultural extension officers in helping in identifying productive farms in their areas.



Picture 4.2: Focus group discussions at Aganang local municipality – 22 September 2011

Focus group discussions were also conducted (see picture 4.2). It is important to note that only crop farmers were interviewed in this study as they were in the majority in the study areas.

4.3 Socio economic characteristics of farmers

As indicated in figure 4.1 the sample consists of both male and female farmers, with 46 percent male and 54 percent female. Various studies have shown that gender is an important variable affecting adoption decisions at the farm level. According to Bayard *et al.*, (2007) female farmers are more likely to adopt natural resource management and conservation practices. It was also emphasised by Burton *et al.*, (1999) that female farmers are indeed important in the choice of agricultural practices to adopt, particularly in regard to conservation or sustainable technology. According to Nhemachena and Hassan (2007) the possible reason for female to adapt is that in most rural smallholder farming communities, men are more often based in towns, and much of the agricultural work is done by women.

Therefore, women have more farming experience and information on various management practices and how to change them, based on available information (Anim, 1999). It was also noted that women spends most of their time in the field than men (StatsSA, 2007).

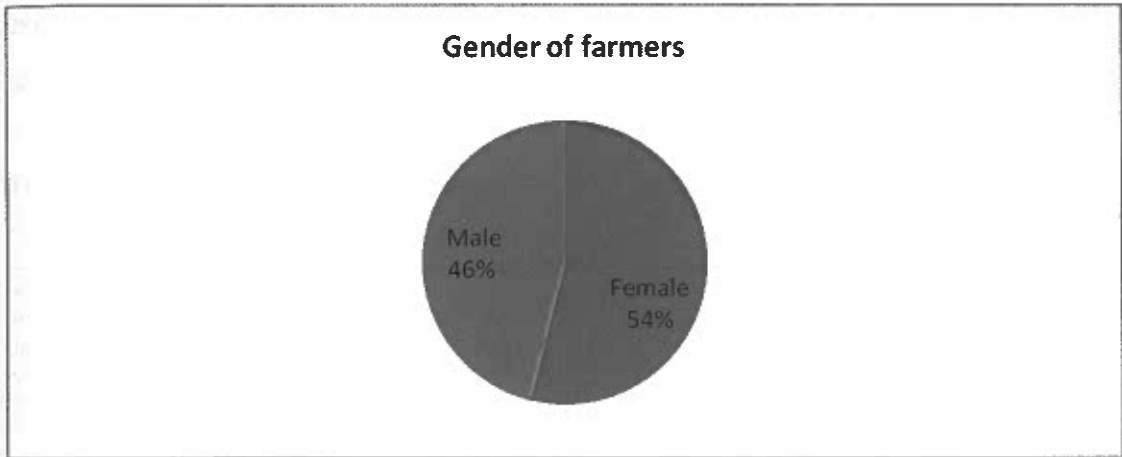


Figure 4.1: Gender of farmers

But according to Bekele and Drake (2003) gender has no significant factor in influencing farmers’ decision to adopt climate change adaptation measures. They stressed that there is a significant difference in farmer’s ability to adapt to climate change due to major differences between them in terms of access to assets, education, credit, technology and input supply.

Table 4.2: Age of farmers

Age	Number of Farmers	Percentages
16 – 24	6	2
25 – 34	44	13
35 – 49	61	18
50 – 64	87	26
65+	102	41
Total	300	100

Looking at the farming activities, most farmers fall in 50 – 65+ age group as indicated in Table 4.2 and this can be as the result of lack of interest in agricultural production from other age categories. This is also because young people have identified other opportunities than farming activities in the province, e.g. tendering opportunities with various government department in the province.

It was also found from literature that there is variation in age on adoption decision. According to Bekele and Dekele (2003) age had no influence on a farmer's decision to participate in climate change adaptation activities. However, according to Bayard *et al.*, (2007) age is positively related to some climate change adaptation measures. Most farmers in Limpopo province assume that old age is associated with more experience and they expect older farmers to adapt to changes in climate while young farmers are expected to have longer planning horizon and thus to take long term adaptation measures.

Table 4.3: Education level of farmers

Education	Number of Farmers	Percentages
No Formal Schooling	20	7
Some Primary Education	63	21
Primary Education Completed	85	28.3
Some Secondary Education	54	18
Secondary Education Completed	33	11
Post Secondary Education	19	6.3
Certificates	8	2.7
University Degree	18	6
Total	300	100

Education and employment are important factors influencing decision to adapt. The majority of the farmers in the study have completed primary education (28.3 percent) while only few farmers have university degree (6 percent) as seen in Table 4.3. The majority of these farmers work fulltime on their farms (97.3 percent) as seen in Table 4.3. According to Anley *et al.*, (2007) improving education and employment is key to stimulate local participation in various adaptation measures and natural resource management initiatives. 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.

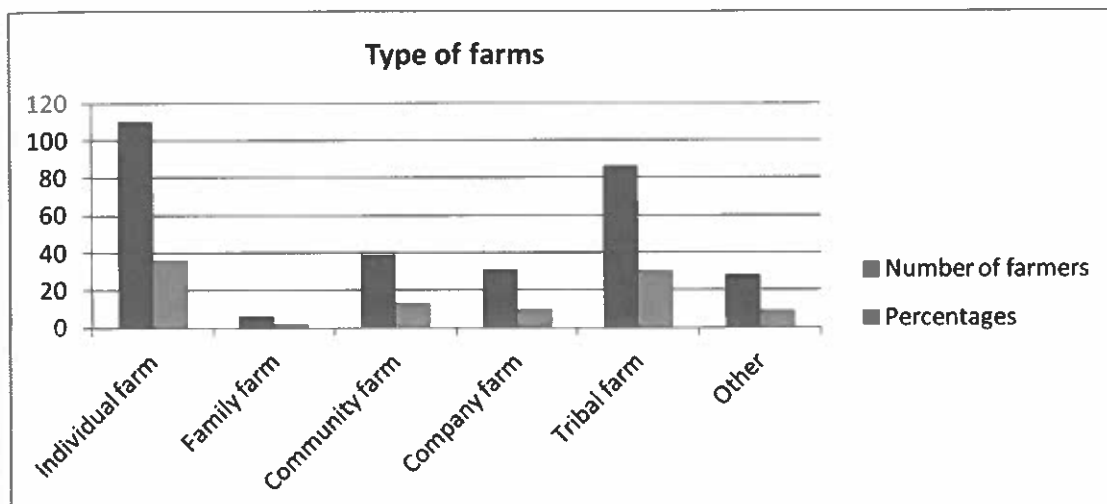


Figure 4.2: Types of farms in both Capricorn and Sekhukhune Districts

As indicated in figure 4.2, 37 percent of farms visited were individual farms while 29 percent were tribal farms. This is true since most farmers were using communal land for agricultural activities. Concerns were raised by farmers who fall in the tribal farm category that they cannot raise capital since most financial institutions doesn't recognise them. Preference is given to those farms with title deeds like individual, family and company farms. The results also show that 13 percent of farms were community farms, 10.3 percent were company farms, 2 percent were family farms while 9 percent failed to answer.

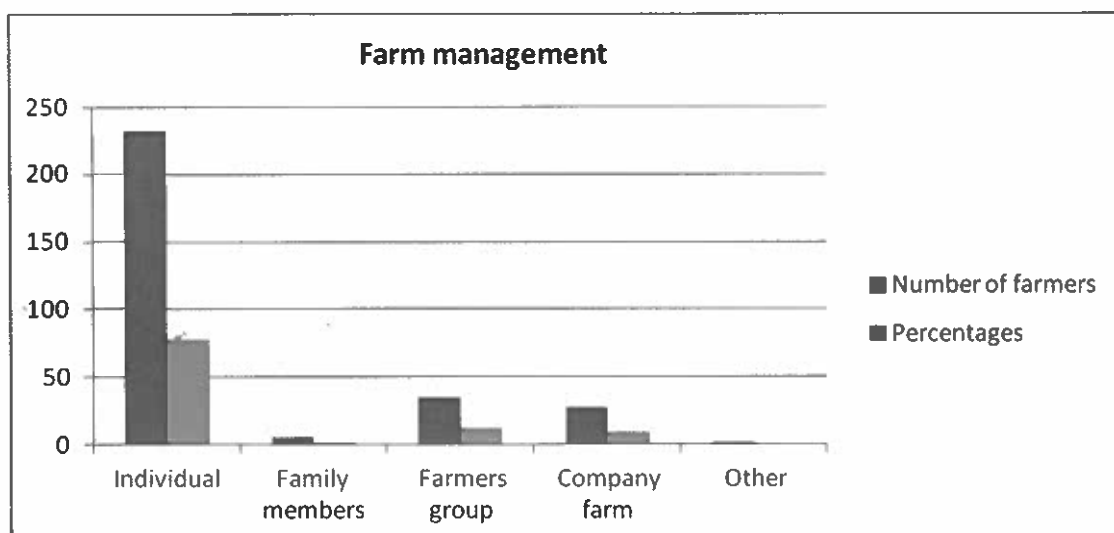


Figure 4.3: Farm management in both Capricorn and Sekhukhune Districts

Most of these farmers prefer to manage their farming operations themselves as shown in figure 4.3. The results indicate that 77 percent of farms were managed by individuals e.g. farm manager or farmer, 12 percent managed by farmers group, 9 percent managed by company while only 1.5 percent were managed by family. In this current environment of changing weather patterns the farm managers' role is highly demanding. Farmers role in managing his/her operation should include planning, organizing, controlling and adapting to any unexpected conditions like climate variability and change.

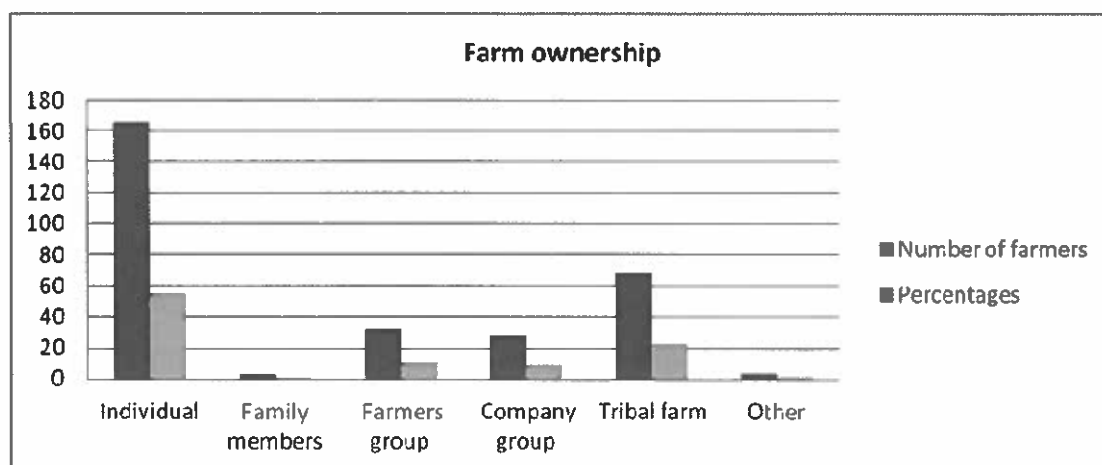


Figure 4.4: Farm ownership in both Capricorn and Sekhukhune Districts

Farm ownership is controlled mostly by individual farmers (55.3 percent) as seen in Figure 4.4. This gives excellent opportunity for adaptation because according to Shultz *et al.*, (1997) land ownership, individually managed is widely believed to encourage the adoption of technologies linked to land such as irrigation equipment or drainage structures. There are also partnerships between this individual farm and big companies since most of them have title deeds unlike communal / tribal farms. Through this partnerships big companies like McCain provides extension services and other support to them. Land ownership is likely to influence adoption if the innovation requires investments tied to land.

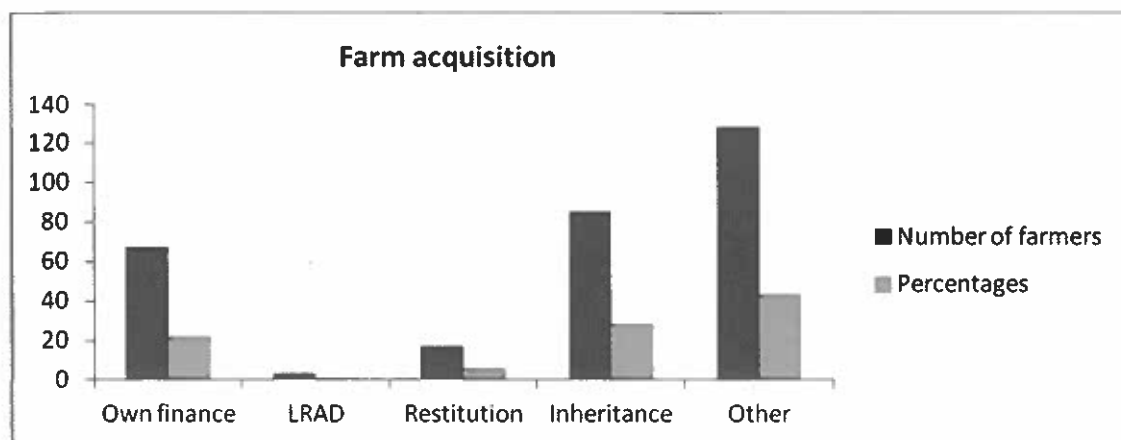


Figure 4.5: Farm acquisition in both Capricorn and Sekhukhune Districts

Farmers were reluctant to explain how they acquired their farms with almost 43 percent failing to give relevant answers due to political reasons mainly because of the current debate about land issue in South Africa, while 28 percent have inherited their farms from their forefathers and 22.3 percent used own finance as shown in figure 4.5. Only 1 percent acquired farms through LRAD and 5.7 percent acquired through restitution. This also indicates the slow pace of land reform in South Africa with government questioning the willing buyer and seller approach.

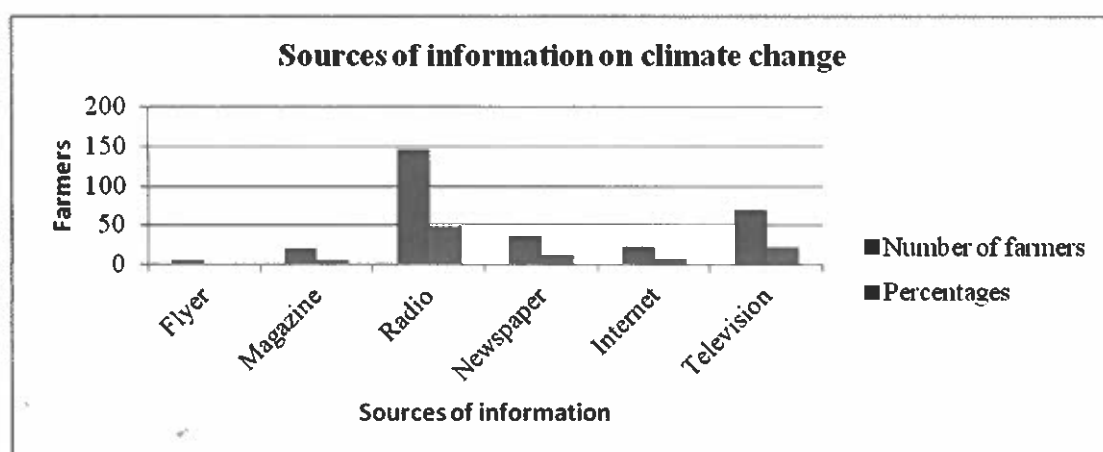


Figure 4.6: Sources of information on climate change

The type of information that they received as indicated in figure 4.6 was mostly through local radios with 48.7 percent of farmers preferring radios as information source. Some farmers prefer television as shown in figure 4.6. It is also clear from the results that flyers, magazines and internet are not popular source of information in both the Capricorn and Sekhukhune Districts. This is because most farmers are in rural areas and access to other

sources of information remains a challenge and they can only access limited information through local chiefs and tribal authority.

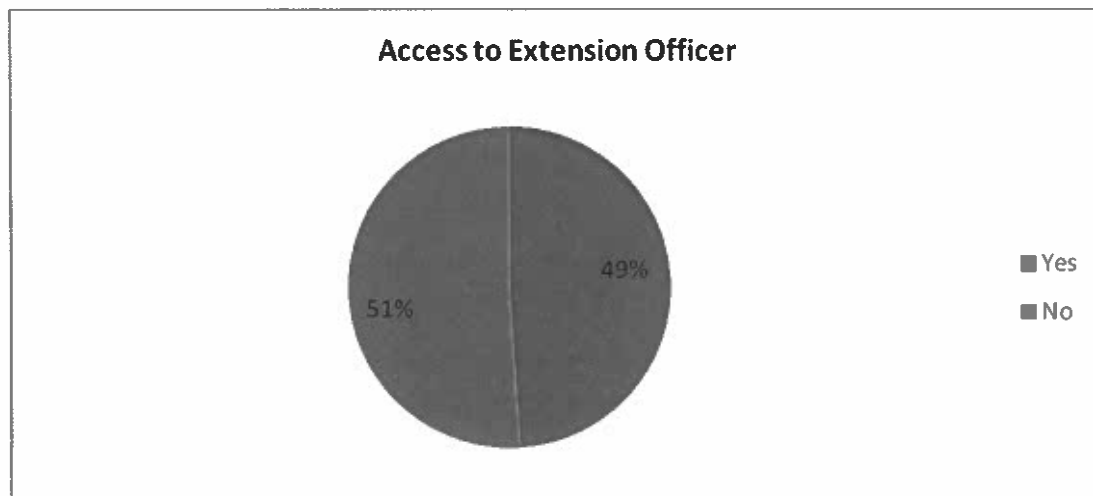


Figure 4.7: Access to Extension Officer

Extension services were received by only 49 percent of farmers as indicated in figure 4.7. This is at least good news because extension services enhance the efficiency of making adaptation decisions. This was also recognised by Adesina and Forson (1995) that of many sources of information available to farmers, extension services is the most important for analysing the adaptation decisions. Adesina and Forson (1995) further hypothesized that access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills.

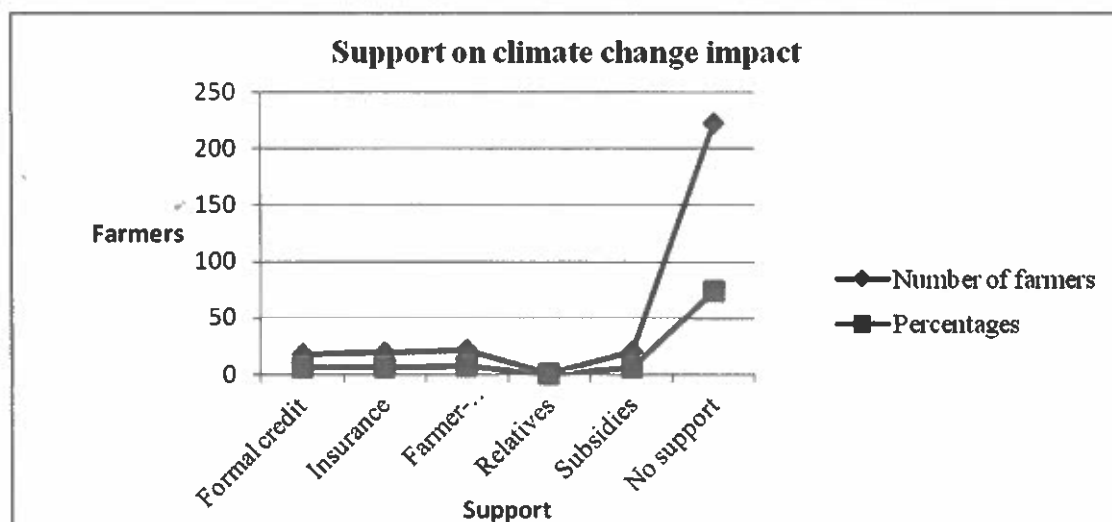


Figure 4.8: Support on climate change impact

At least 74 percent of farmers received no support to adapt against changing weather patterns as indicated in figure 4.8. Only 4.7 percent farmers received credit; 6.3 percent received insurance and 6.7 percent received subsidies. This is not good at all because lack of credit, insurance and subsidies limit the ability of farmers to get the necessary resources and technology they might need in order to adapt to climate change. According to Kandlinkar and Risbey (2000) since most farmers in Africa are operating under resource limitations: (a) Lack of credit, (b) Subsidies and (c) Insurance will accelerate farmers' failure to meet transaction costs necessary to acquire adaptation measures as a result of unexpected weather patterns.

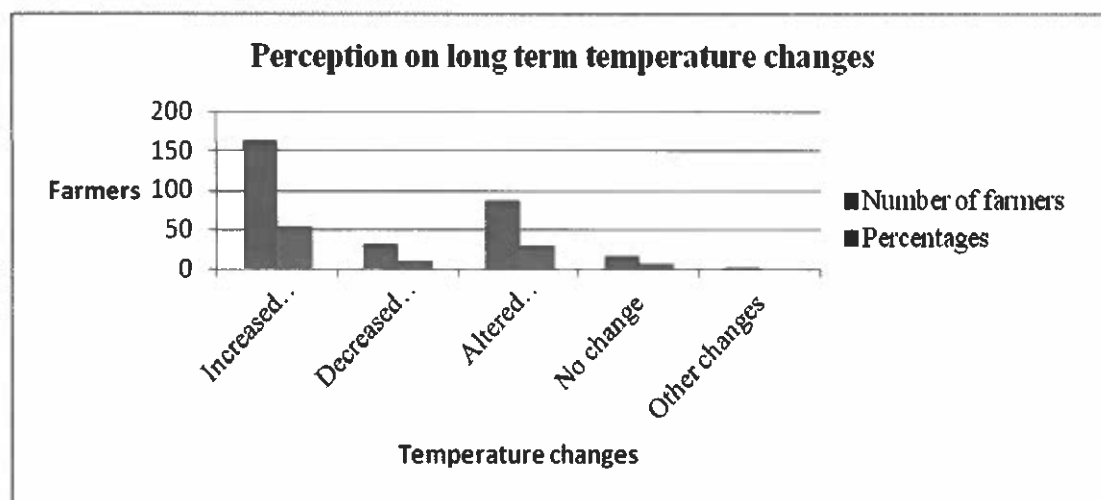


Figure 4.9: Perception on long term temperature changes

Perceptions on long-term temperature are divided into five as can be seen in figure 4.9. The results indicate that 54.7 percent of farmers perceive that long-term temperatures are increasing. This is true as Jarraud (2011) emphasised that over the last ten years from 2001 to 2010, global temperatures have averaged 0.46°C above the 1961-1990 average, and are the highest ever recorded for a 10-year period since the beginning of instrumental climate records. Only few farmers believed temperature was decreasing, which is an indication that there is change in temperature or lack of understanding amongst farmers due to poor dissemination of climate advisory information from the extension officers or any government agents that deals with climate advisory.

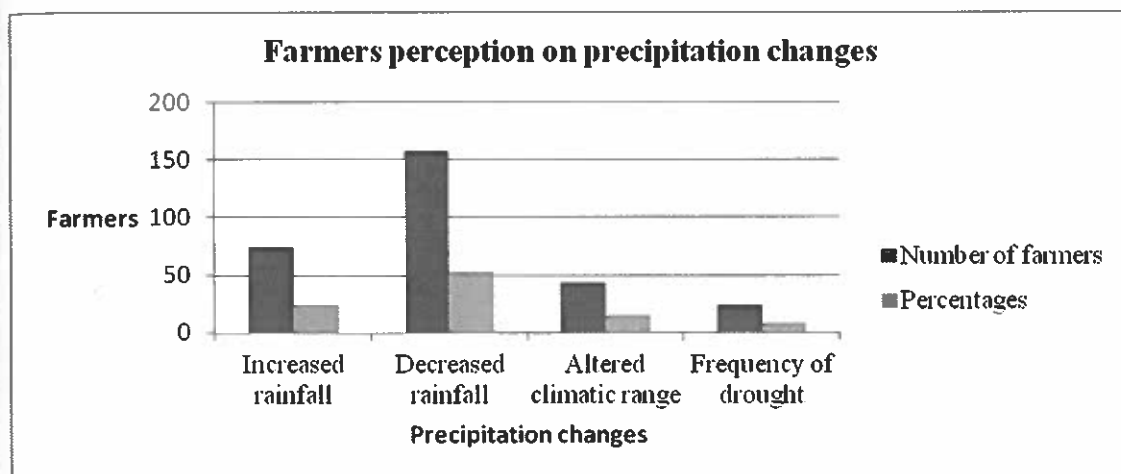


Figure 4.10: Farmers perception on precipitation changes

On the other hand, the overall perception on long term changes in precipitation is that Limpopo province as indicated in figure 4.10 is getting drier and that there are pronounced decreased rainfall altered climatic changes and frequency of droughts (52.7 percent, 15 percent and 8 percent). This shortage of water will have a negative impact on agricultural production.

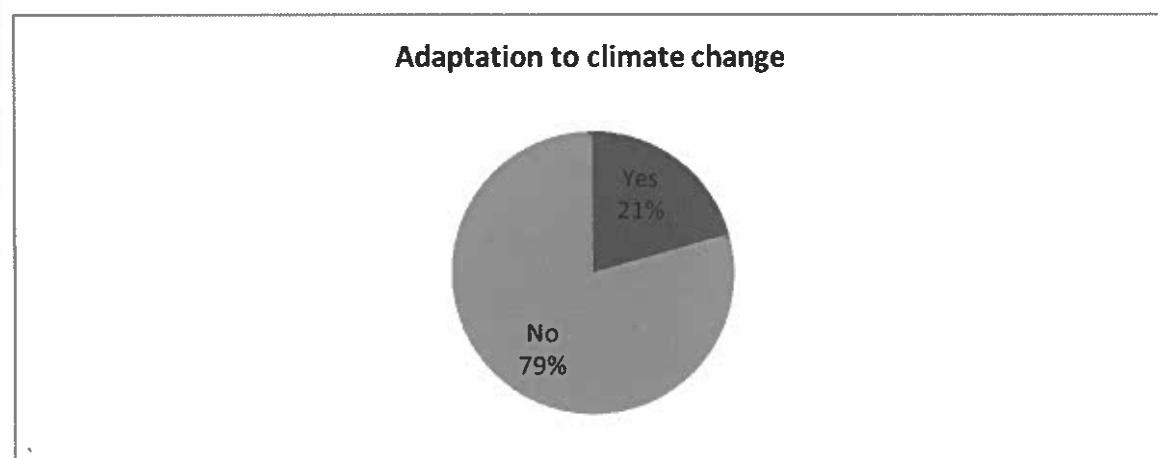


Figure 4.11: Adaptation to climate change

Based on farmer's response in previous figures, it is not surprising to find 79 percent of farmers being unable to adapt as shown in figure 4.11. According to Vogel and Reid (2005) the most important thing to adapt against changing weather patterns is to strengthen social, economic and environmental resilience of the most vulnerable communities.

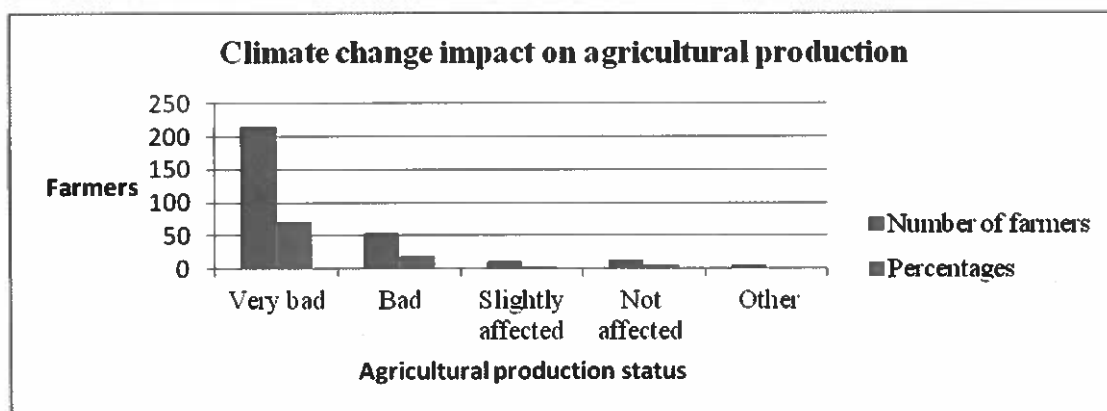


Figure 4.12: Climate change impact on agricultural production

The climate variability and change situation in Limpopo province has in fact affected farmers agricultural production as evident in Figure 4.12, whereby 71.3 percent of farmers agreed that climate change has in fact affected their agricultural crop production very bad. This is true as Mpandeli (2005) found that the impact of lower rainfall has negative effects on the agricultural sector and low rainfall will result in (a) Decreases in agricultural activities, (b) Loss of livestock, (c) Shortage of drinking water, (d) Low yields and shortage of seeds for subsequent cultivation.



Picture 4.3: Chillies damaged by increased temperature in Capricorn District, Limpopo province

Increased temperature can results in damaged chillies as indicated in picture 4.3. This can be as results of decreased rainfall, frost and high temperatures which can interfere with fruit setting. Increased temperature also increase mortality in the elderly population, increased heat stress for wildlife, lower crop yields and increased cooling demand/reduced energy supply reliability



Picture 4.4: Onions damaged by increased temperature in Capricorn District, Limpopo province

Increased temperatures can also damage onion production as evident in picture 4.4. Lack of rainfall in both Capricorn and Sekhukhune districts accelerated poor harvest since onions requires approximately 400 to 600 mm of water during growing season and extreme high temperatures will not promote flowering and bulb formation as shown in picture 4.4.



Picture 4.5: Maize damaged by frost/hail in Sekhukhune District, Limpopo province

Frost and hail can damage maize production as evident in picture 4.5. Maize requires more irrigation as it produces very high yields under that condition. In Limpopo province for example, frost / hail has damaged maize at all growth stages as seen in picture 4.5. It also important to note that Maize crop is a staple food in the province, so if maize is damaged by frost this pose serious threat to food availability and food security in the province.



Picture 4.6: Butternuts damaged by hail in Sekhukhune District, Limpopo province

Hail damage is also popular in butternuts production as shown in picture 4.6. Butternut is easily damaged by hail, slight frost, high temperatures and lack of water. It needs good adaptation measures to survive. Furthermore, hailstorm activity and hailstorm damage are likely to increase in the future if average temperatures or extremes in temperatures rise due to climate variability and change (IPCC, 2007).



Picture 4.7: Farmer showing tomatoes damaged by hail and high temperatures in Limpopo province

Tomato damage is high in Limpopo province as seen in picture 4.7. This is as results of high temperatures, hail, hot and dry winds which cause the occurrence and spread of foliar diseases. Problems with vegetable fruit set and quality will occur. As seen in picture 4.7, flower and fruit abortion are common responses to heat stress as a result of the general failure of successful pollination and fertilization.

4.4 Farmers response to climate variability and change: Impact on their livelihoods

Climate variability and change impacts on farmer's livelihoods are already being identified, signaling an urgent need for response measures that will minimize current vulnerabilities.

Table: 4.4: Farmers response to climate variability and change impact on their livelihoods

Variable	Number of Farmers	Percentages
<i>Low income</i>		
Yes	274	91.3
No	26	8.7
<i>Increased socio economic problems</i>		
Yes	141	47
No	159	53
<i>Increased unemployment</i>		
Yes	214	71.3
No	86	28.7
<i>Reduced cultivated lands</i>		
Yes	25	8.3
No	275	91.7
<i>Reduced fertility</i>		
Yes	212	70.7
No	88	29
Total	300	100

It is evident in Table 4.4 that farmer's livelihoods are being disturbed by changing weather patterns where 91.3 percent. However, 71.3 percent indicate that there is high unemployment rate in both Capricorn and Sekhukhune Districts. At least 70.7 percent also mentioned that there is reduction of fertility in both districts. This results is in line with the third assessment report of intergovernmental panel on climate change which identified a range of impacts associated with climate variability and change. This included (a) low income, (b) increased unemployment and(c) reduced soil fertility for farmers and households (IPCC, 2007).

4.5 Farmers response to climate variability and change: Impact on agricultural production

Table: 4.5: Farmers response to climate variability and change: Impact on Agricultural production

Variable	Number of Farmers	Percentages
<i>Reduced crop yields</i>		
Yes	268	89.3
No	32	10.7
<i>Increased crop diseases</i>		
Yes	135	45
No	165	55
<i>Reduced livestock production</i>		
Yes	18	6
No	282	94
Total	300	100

Table 4.5 indicates that climate variability and change negatively affect crop yields. This has resulted in 89.3 percent of farmers agreeing that climate variability and change do reduce their crop yields as shown in Table 4.5. This situation is not surprising as IPCC (2011) has indicated that climate variability and change will have a serious impact on crop yields in developing countries including Africa. Only 18 percent of farmers agreed that climate variability and change has reduced their livestock production. This is not surprising because majority of farmers interviewed were crop farmers in those selected municipalities in Limpopo province.

4.6 Farmers response to climate variability and change: Impact on Food security

Table: 4.6: Farmers response to climate variability and change: Impact on Food security

Variable	Number of Farmers	Percentages
<i>Unemployment</i>		
Yes	178	59.3
No	122	40.7
<i>Low income</i>		
Yes	244	81.3
No	56	18.7
<i>Scarcity of food</i>		
Yes	247	82.3
No	53	17.7
<i>Increased food prices</i>		
Yes	201	67
No	99	33
<i>Lack of local markets</i>		
Yes	164	54.7
No	136	45.3
Total	300	100

Climate variability and change affects food production directly through changes in agro-ecological conditions and indirectly affecting income, food prices, markets as shown in Table 4.6. The majority of farmers interviewed felt that climate variability and change has indeed affected their income, food prices and markets.

The results show that 81.3 percent had low income and then 82.3 percent are facing food scarcity while 54.7 percent of farmers mentioned that lack of local markets is a serious challenge in the district. This caused increased food prices and due to lack of markets and also poor support from government; however climate variability and change are just additional climate stressors. This situation was further emphasised by FAO (2010) that climate variability and change will affect dimensions of food security, namely (a) Food availability (Production and Trade) (b) Food access and (c) Utilisation.

4.7 Univariate analysis model.

Table 4.7: Univariate analysis of potential determinants of agricultural production

Variable	Total	Agric Production (%)	OR [95%CI]
Sex of farmers			
Male	136	6.6	1.00[0.373 – 2.403]
Female	164	6.3	1
Employment			
Working fulltime	292	6.5	0.72[0.285 – 1.141]
Working part-time	8	0	1
Information of climate change			
Yes	171	2.9	4.50[1.585 – 12.697]
No	129	11.9	1
Adaptation to climate change			
Yes	55	1.8	5.01[1.654 – 38.383]
No	245	8.5	1
Information received through extension Services			
Yes	146	4.1	2.45[1.585 – 12.697]
No	154	9.5	1

OR= Odds ratio; 95%CI = 95% confidence intervals.

According to Table 4.7 the odds of being affected by climate change are 1.00 percent higher for male farmers than female farmers. This situation is not surprising because it should be acknowledged that women play a vital role in supporting households and communities to adapt to climate change through experience gained in agricultural production. In Africa, for instance, women are the primary producers of staple food and

they contribute much of labor that will go into coping with climate risks through soil and water conservation (UNDP, 2009). This situation is not different from Limpopo province, where most information was given by female farmers. According to UNDP (2009) across developing countries women's leadership in natural resource management is well recognized. Women for centuries have passed on their skills in water management, forest management and the management of biodiversity, among others.

The studies by Nhemachena and Hassan (2007) also acknowledge women contribution in agricultural sector in relation to climate change. They have concluded in one of their studies that women are doing much of agricultural work while men are more often based in towns and this enables women to have more experience and information on various management practices and how to change them based on available information on climatic conditions. Through these experiences, women have acquired valuable knowledge that will allow them to contribute positively to the identification of appropriate adaptation and mitigation techniques and thus determining agricultural production (Nhemachena and Hassan, 2007). The odds of being affected by climate change are 0.72 times less for fulltime farmers than those part-time farmers as indicated in Table 4.7. This is true because being fulltime farmer increases chances of the ability to take adaptation options.

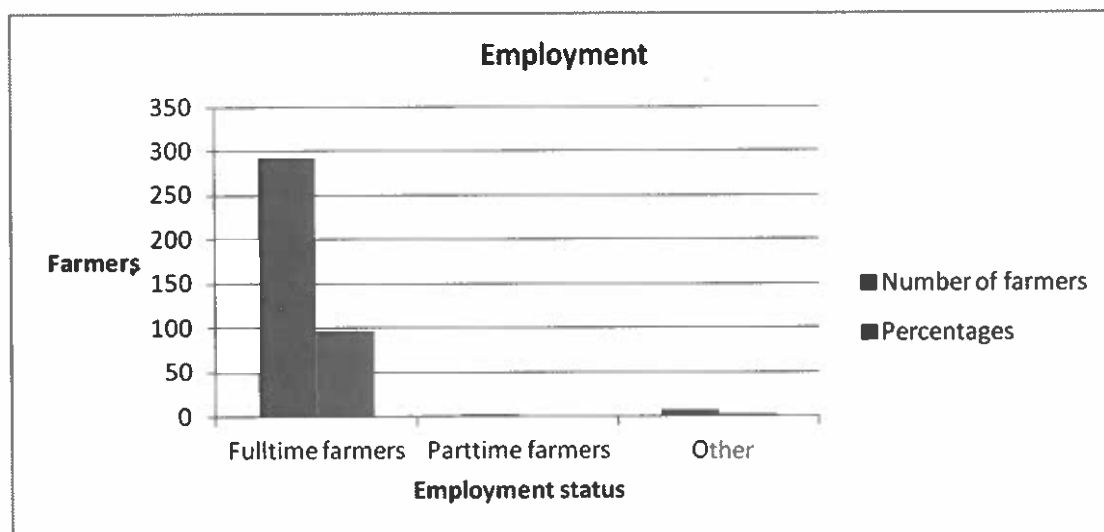


Figure 4.13: Employment status in both Capricorn and Sekhukhune Districts

The response of farmers in Limpopo province as indicated in figure 4.14 is in line with the study conducted by Nhemachena and Hassan (2007) that fulltime farmers will not be affected much by climate change because they are more likely to have more information and knowledge on changes in climatic conditions than part-time farmers. Most of these farmers can also be targeted in promoting adaptation management by government to other farmers who do not have relevant experience and are not yet adapting to climate variability and change.

As indicated in Table 4.7 the odds of being affected by climate change is 4.50 percent times higher for farmers with information on climate change than those without information on climate change. This situation shows a bleak picture on access to climate information in Limpopo province. As seen in Figure 4.6, the majority of farmers receive climate change information through radios (48.7 percent) which may indicate that farmers need to get information from other sources to adapt. Limpopo province farmers should understand that information regarding climate change projections, adaptation options and agricultural activities are not easily available on radio and this increases high risks associated with climate variability and change. According to Baethgen *et al.*, (2003) availability of climate and agricultural information helps farmers to make comparative decisions in agricultural production and this allows them to better choose strategies that would counteract climate variability.

Another disturbing response is that of access to extension services by farmers. According to Table 4.7 the odds of being affected by climate change is 2.46 times higher for farmers that received information through extension services than those who did not receive information through extension services. This situation does not surprise me because some of the farmers especially resource poor farmers, were complaining that some extension officers do not have relevant qualifications to do the job. Again some extension officers were also complaining that government is not organising relevant training courses that deal with climate variability and change and agricultural production. This is a clear indication that extension officers need to be re-trained in order to provide valuable information to the farmers so that farmers can value them. As Mmbengwa (2009) emphasised that extension services have an important role to play in assisting farmers to acquire new technology, skills, innovation and production advice. So Limpopo farmers and government should priorities extension service because it will significantly increase farmer awareness and the

ability to deal with climate impacts or changing climatic conditions as well as adaptation measures in agricultural production.

According to Table 4.7 the odds of being affected by climate change are 5.01 times higher for farmers that can adapt to climate change than those who cannot adapt to climate change. This situation shows that even if some farmers are trying to adapt, the impact of climate change on agricultural production is a reality. The majority of farmers in those districts have agreed that they don't have capacity to adapt but the results also shows that even those who adapt are at risk against changing weather patterns. According to Maddison (2007) situation like this can be addressed by governments like DAFF, ARC and SAWC to raise awareness of the changes in climatic conditions through appropriate communication pathways that are available to farmers such as extension services, farmer groups, tribal authorities, local municipalities, radio and televisions among others. This needs to be accompanied by the various crop and livestock management practices that farmers could take up in response to forecasted changes in climatic conditions such as varying planting dates, using irrigation, or growing crop varieties suitable to the predicted climatic conditions.

Table 4.8: Univariate analysis of potential determinants of unemployment

Variable	Total	unemployment (%)	OR [95%CI]
Sex of farmers			
Male	136	36	1.43[1.008 – 2.291]
Female	164	55	1
Information of climate change			
Yes	171	41.5	0.93[0.580 – 1.481]
No	129	39.7	1
Adaptation to climate change			
Yes	55	24	0.75[0.412 – 1.372]
No	245	78	1
Information received through extension services			
Yes	146	54.1	0.32[0.195 – 0.516]
No	154	27.2	1

OR= Odds ratio; 95%CI = 95% confidence intervals.

According to Table 4.8 the odds of unemployment as a result of climate variability and change are 1.43 times higher for male farmers than for female farmers. It was mentioned earlier that women are the world's principal producers of primary staple foods (rice, wheat, maize), which account for up to 90 percent of the food eaten by poor rural populations throughout the world and between 60 percent and 80 percent of foods in most less

developed countries (UNDP, 2009). Women can also be self employed because of their role in collecting firewood and other biomass products. Some women farmers in Limpopo province are selling firewood and composts to the communities. So these activities put women far better than men in terms of unemployment as a result of climate variability and change as reflected in Table 4.8. So women should be acknowledged in their role in poverty reduction strategies, designing of creative tools to adapt to unemployment and their increased off- farm employment (UNDP, 2009).

According to Table 4.8 the odds of being unemployed as a result of climate variability and change are 0.93 less for farmers with information of climate change than those with no information of climate change. This reflects the importance of information on being employable in other off – farm sectors like mining and local government. In this regard farmers can sell their knowledge and skill to do other non farming activities. The same applies to those farmers who can adapt to climate variability and change, where the odds of being unemployed as a result of climate variability and change are 0.75 less than those that cannot adapt. Here farmers can use their adaptation strategies to become employable in other off – farm sectors.

Lastly in Table 4.8 the odds of unemployment as a result of climate variability and change are 0.32 less for farmers who receive information through extension services than those that do not receive information through extension services. This shows that extension services provide an important source of information for farmers and it increase farmers management, technical skills which farmers can use in other off – farm sectors. Farmers who received extension services can also train other neighbouring farmers and use the train the farmers principles regarding agricultural production and climate variability and change.

Table 4.9: Univariate analysis of potential determinants of food scarcity

Variable	Total	Food scarcity (%)	OR [95%CI]
Sex of farmers			
Male	136	18.4	1.00[0.373 – 2.403]
Female	164	17	1
Information of climate change			
Yes	171	13.5	2.01[1.103 – 3.667]
No	129	23.8	1
Adaptation to climate change			
Yes	55	10.9	1.78[1.013 – 4.464]
No	245	17.9	1
Information received through extension Services			
Yes	146	17.8	0.95[0.517 – 1.730]
No	154	17	1

OR= Odds ratio; 95%CI = 95% confidence intervals.

As indicated in Table 4.9 the odds of farmers to face food scarcity are 1.00 times higher for male farmers than female farmers. This is true as also seen in Table 4.7, which further emphasise that women's knowledge of seed varieties, cultivation, storage, and use is a valuable form of human capital that makes them food secure. According to FAO (2011) women also plays a important role in postharvest activities and as grains or other crops come in from the fields, women decides what will be stored , processed and saved for next year crops. These activities make women farmers more food secure than men farmers. According to Table 4.9 the odds of farmers to face food scarcity in 2.01 higher for those that have access to climate change information than those who did not have access to information. Again the results raised the issue of type of information farmers are receiving and the source they use in getting accurate information regarding climate variability and change. The following sources are more popular among farmers in the Limpopo province: (a) Radios (b) Television (c) Newspapers and (d) Magazines.

As indicated in Table 4.9 the odds of farmers to face food scarcity are 1.78 times higher for farmers who adapt to climate variability and change than those who cannot adapt to climate variability and change. In views of this, it can be deduced that farmers do not have enough adaptation strategies hence they are still vulnerable to food scarcity. The odds of farmers to face food scarcity are 0.95 times less for farmers who receive information through extension services than those who do not receive information through extension services. Through extension services farmers can receives skills, knowledge to produce food. It was also supported by Mmbengwa (2009) who said farmers with access to

extension services have better chance of engaging more profitably in agriculture than those that have no access.

Table 4.10: Univariate analysis of potential determinants of food prices

Variable	Total	Food Prices (%)	OR [95%CI]
Sex of farmers			
Male	136	32	1.07[0.639 – 1.800]
Female	164	34	1
Information of climate change			
Yes	171	31.6	1.16[0.714 – 1.894]
No	129	34.9	1
Adaptation to climate change			
Yes	55	27.3	1.26[0.651 – 2.436]
No	245	32.1	1
Information received through extension services			
Yes	146	42.5	0.41[0.246 – 0.675]
No	154	23.1	1

OR= Odds ratio; 95%CI = 95% confidence intervals.

According to Table 4.10 the odds of being affected by high food prices as results of climate change are 1.07 times higher for male farmers than female farmers. The odds of being affected by high food prices as results of climate change are 1.16 times higher for farmers with climate change information than farmers without climate change information. This again raise the question of the type of information farmers are receiving and which source they are using. Limpopo province farmers should acknowledge the importance of information because though information farmers can be able to know the current trends and estimates on food prices and measures to use for adaptation.

Table 4.10 further emphasise that the odds of being affected by high food prices as a results of climate change are 1.26 times higher for farmers that can adapt to climate change than those that cannot adapt to climate change. This shows that farmers are still vulnerable to high food prices even if they adapt in some instances. The results also shows that extension services is very important to adapt against high food prices since the odds of being affected by high food prices as results of climate change are 0.41 times less for farmers who receive information through extension services than farmers who did not receive information through receive extension services.

4.8 Summary

- 1) Results indicate that farmers are aware that Limpopo province is getting warmer and drier with increased frequency of droughts, changes in the timing of rains, observed trends of temperature and precipitation. The implication is that farmers need to adjust their management practices to ensure that they make efficient use of the limited rainfall and water resources for food production and other needs.
- 2) In this chapter farmers also identified that lack of information about climate change and variability, lack of information through extension services, poor adaptation capacity, lack of source of information as important constraints. Addressing these issues can significantly help farmers tailor their management practices to warmer and drier conditions.
- 3) Univariate analysis also confirmed that being full time farmer, gender, information on climate change, information received through extension services and adaptation to climate change are some of the important determinants of agricultural production, food scarcity and unemployment.
- 4) The results from this chapter also showed that the impact of lower rainfall has negative effects on the agricultural sector and low rainfall and increased temperature will result in (a) Decreases in agricultural activities (b) Loss of livestock (c) Shortage of drinking water (d) Low yields and shortage of seeds for subsequent cultivation. The chapter emphasized that the most important thing to adapt against changing weather patterns is to strengthen social, economic and environmental resilience of the most vulnerable communities. It was further emphasized that access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills. So Limpopo farmers and government should priorities extension service because it will significantly increase farmer awareness of changing climatic conditions as well as adaptation measures in agricultural production

CHAPTER 5

Climate variability and change in Limpopo province

5.1 Introduction

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity and is a key scientific and policy issue of great concern to all humankind (Mpandeli *et al.*, 2007). According to Mpandeli (2009) climate change can be regarded as the silent enemy likely to affect already high risk and stressed agro ecosystems as the effects of climate change are not immediately visible. Limpopo province is particular vulnerable to climate variability and change as agricultural production depends on climatic conditions and largely on the quality of the rainy season. According to Letsatsi – Duba (2009) climate change in Limpopo province is taking place in the context of other developmental stresses, notably poverty, unemployment and food insecurity which it is feared that it will exceed the limits of adaptation in other parts of the province. It is thus important to develop and implement effective adaptation measures so that climate-related risks and opportunities might support development objectives within provincial policy decision making processes.

According to Nesamvuni (2009) it is expected that in Limpopo province, drought will worsen and last for a long time mostly due to climate variability and change. Nesamvuni (2009) further emphasised that the department of Agriculture in Limpopo is focusing its research on the immediate and long term effects of global warming and related phenomena. “Global warming and climate change are no longer futuristic buzz words; they’re tangible realities already affecting us” (Nesamvuni, 2009).

5.2 Climate variability and change in Capricorn District

Climate change is one of the biggest challenges of the century and is regarded by all spheres of government including Capricorn district, as one of the greatest threats of our planet and our people (Mpandeli, 2009). The rural community of Capricorn district places

great emphasises on growing maize and vegetables. However, adverse climatic conditions will have a bearing on their agricultural production (Mpandeli *et al.*, 2005). This is more likely to affect women more than men as they spend most of their income on food purchases (Makhura, 2001). It could also mean that they now have to spend more time on food gathering processes than before, as less food will be available to families.

“Climate change is happening now and our district will certainly not be spared the effects of global warming and climate change and we must work with all stakeholders in order to increase our mitigation and adaptation efforts towards doing our fairly share by reducing greenhouse gases emissions within the district and therefore our carbon footprints and also instituting measures to adapt to the unavoidable effects of climate change and global warming” (Makunyane, 2009). According to CDM (2011) the following actions will be taken at the district level against climate variability and change:

- Development of a district climate change mitigation and adaptation framework / strategy
- Launching a clean fires campaign - outreach event to roll out the department of Minerals and energy's Basa Njengo Magogo fire-making methodology in priority areas
- Air quality management section will establish an information management system wherein all greenhouse gas emissions will be reported and recorded
- Greening / tree planting projects
- Identification of clean development mechanism (CDM) projects for purposes of carbon sequestration or carbon trading
- Development of a tool to measure the carbon footprint of municipal activities
- Retrofitting municipal buildings to make them more energy efficient and environmentally friendly
- Launching energy efficiency campaigns
- Develop Green Building guidelines – these guidelines will promote the incorporation of environmental friendly technology into building design
- Instituting awareness programmes

5.3 Climate variability and change in Sekhukhune District

Sekhukhune is a ramshackle district on the edge of the province. It is particularly attached to agriculture. The effects of climate change have been felt in recent years and have caused difficulties to the agricultural sector (GSDM, 2005). Farmers will have to cope with droughts, floods, soil degradation and silted water sources. Many communities in Sekhukhune district are facing difficulties in coping with existing climatic variability and recurrent extreme weather patterns e.g drought, frost, fires ect.

Drought, floods and other extremes of weather are seriously disrupting growth and poverty reduction processes in Sekhukhune district. It was also noted by Maponya (2008) that climate change in Sekhukhune district is having a direct impact on people's livelihood assets – including their health, access to water and natural resources. This is also supported by Oni *et al.*, (2003) when these researchers said agricultural production in Limpopo province including Sekhukhune district is at risk due to drought and other natural disasters.

Most farmers in Sekhukhune have long maintained a suite of indigenous strategies to manage risk and deal with poor overall productivity in spite of low returns to land, labour and capital. It is generally acknowledged that low – resource agriculture is no longer capable of meeting the livelihoods demands of rising populations (Makhura, 2001). The reality is that climate is changing and it will have a negative impact on agricultural production. The community in Sekhukhune is more at risk from the impact of climate variability and change because of their limited capacity to cope with existing climate variability and future change (Mpandeli, 2006).

5.4 Drought impacts in the Limpopo province

Limpopo Province is characterized by high climatic variability. This is a serious problem in the province considering the fact that the province is in a semi arid area with low, unreliable rainfall (Mpandeli, 2006). The impact of lower rainfall has negative effects on the agricultural sector, low rainfall resulting in decreases in agricultural activities, loss of livestock, shortage of drinking water, low yields and shortage of seeds for subsequent cultivation (Mpandeli, 2006 ; Mpandeli pers.comm, 2011).



Picture 5.1: Drought impact in Limpopo province

Source: ARC- ISCW (2007)

As indicated in picture 5.1, Limpopo is a drought prone province which faces challenges of drought from time to time. As a result of the severe drought the province experienced reduced grazing and water for livestock and irrigation which negatively impacted the agricultural sector. Limpopo province was worst affected by drought in the past eight years where dams were only 50 percent full, compared with 84 percent in the late nineties. In North West, dams were 53 percent full compared with 85 percent in late nineties, while in Mpumalanga were 49 percent full as compared with 72 percent in the late nineties. Dams in KwaZulu-Natal were 68 percent full compared with 87 percent in the late nineties. Dams in the Western Cape were also affected, being only 70 percent full as compared with 86 percent in the late nineties (Naidu , 2003).

Table 5.1: Drought stricken districts in Limpopo province

District	Amount received	People affected
Capricorn	5.3 million	159 000
Waterberg	5.6 million	167 000
Sekhukhune	5 million	112 000
Mopani	4.8 million	197 000
Vhembe	8.4 million	256 000

Source: StatsSA (2006)

As indicated in Table 5.1, in 2004 drought stricken districts in Limpopo Province received money from national government to ensure that communities have adequate access to

water. But in 2006/07 farmers had to buy food for their animals as grazing in some parts of the province had been reduced dramatically due to low rainfall and hot conditions. In December 2007 and March 2008 drought stricken farmers in Limpopo were given emergency feed worth 45 million for the disaster drought assistance scheme (LDA, 2009).

According to Letsatsi- Duba (2009) the provincial department of agriculture spent R24 million in the previous financial year to implement livestock water infrastructure distributed in all five districts. The money was used for the silting 10 earth dams for livestock water; equipping of 130 boreholes with windmills and pumps; construction and repair of 80 drinking troughs and the installation of 10 000 litre water storage tank to the equipped borehole (Letsatsi – Duba, 2010).

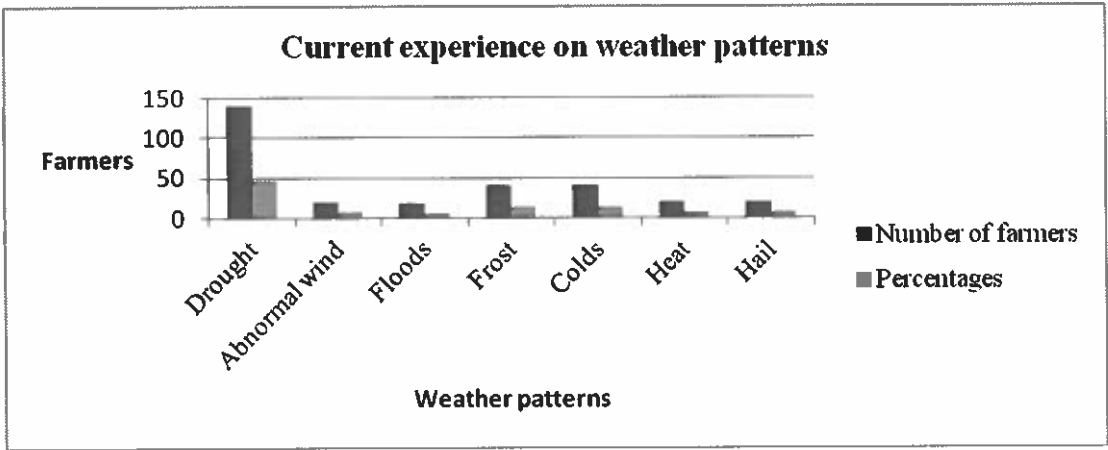


Figure 5.1: Current experience on weather patterns in Limpopo Province

It also evident from figure 5.1 that current Limpopo province weather is dominated by drought as observed by 47 percent of farmers. This observation is in line with Letsatsi- Duba (2009) statement when she said Limpopo province is a drought prone province which faces challenges of drought from time to time.



Picture 5.2: Drought impact in Limpopo province

Source: ARC- ISCW (2007)

As a result of the severe drought the province experienced reduced grazing and water for livestock and irrigation which negatively impacted the agricultural sector as seen in picture 5.2. The picture also indicate that drought impact in Limpopo province is affecting various commodities such as crops , livestock etc in all five districts and drought has been recurring in the past years.

Drought in Sekhukhune district is having serious ecological and economic consequences and will pose an increasing challenge to communities as the global climate is changing. As result of drought in Sekhukhune, there is a serious water shortage throughout the district which limits the scale of farming operations and raise input costs for famers due to the need to install expensive irrigation systems. It is currently estimated that 65 000 ha of developed land cannot be used due to water constraints (GSDM, 2011).

According to GSDM (2011) Sekhukhune district has been hotter and drier over the last ten years. This condition will have a serious impact on agricultural production in the district since agriculture is a critical source of employment for the people of Sekhukhune. Water management policies are necessary and water – conservation farming practices should be adopted. Drought in the Capricorn region is causing serious challenges since more than 80 percent within the district depends on groundwater supply and it is globally known and understood that it is sometimes difficult to manage the groundwater quality due to restricted resource availability, quality of water, erratic precipitation, drought and water management issues (Van Dyk *et al.*, 2005). Due to the occurrence of drought in the district its impact on water resources, people's livelihood and health has become serious.

The agricultural sector is also seen as an important source of livelihood for the district especially those in rural areas, but with extreme weather like drought it is going to be very difficult for people to cope. It is quite disturbing that in some parts of the district, farmers are already forced to sell their livestock because of drought conditions. This will in turn place a serious challenge for agriculture not only in the province but South Africa as a whole. According to Makhura (2001) a sharp decline in agricultural production would not only have implications for a province or country but also for the region as a whole.

5.5 Agricultural activities in Sekhukhune District

According to StatsSA (2006) agriculture is estimated to account for 2.4 percent of gross domestic product in 2004, declining from 3.4 percent of gross domestic product in 1999. Agriculture is a critical source of employment for the people of Sekhukhune district. However according to Mpandeli *et al.*, (2005) households in Capricorn, Mopani and Sekhukhune district are farming under difficult environment, and some of the households are facing major problems of high input costs and changing in climate patterns. According to StatsSA (2006) Sekhukhune district has 70 percent subsistence and 30 percent commercial farming activities.

In Sekhukhune district agriculture is characterised by two different sub – sectors driven by two different populations. There is a large – scale , white – farmer dominated commercial agriculture cluster around Groblersdal and Marble Hall that has access to costly inputs and mass – produce goods for local , national and some instances international markets (StatsSA, 2011). Secondly there are small – scale subsistence and emerging black operations dispersed throughout the district characterised by low levels of production and informal sale of goods to the local population. It is due to this second population that Mpandeli *et al.*, (2005) emphasise that financing of small – scale agriculture should be encouraged as it will trigger agricultural transformation and lack of access to credit among small scale farmers has a negative effects in agricultural development in most parts of South Africa (Makhura, 2001).

Sekhukhune district is characterised by a variety of products including citrus fruit, table grapes, vegetables, maize, wheat, cotton and livestock. Commercial farming cluster around Marble Hall and Groblersdal produce citrus, grapes and vegetables (Makhura, 2001).

Farmers also produce crops like wheat, soya, maize and cotton. Livestock production includes cattle, ostrich and poultry. The majority of these commercial produce is sold locally or to nearby major markets of Johannesburg, Pretoria, Polokwane and Nelspruit (GSDM, 2011). Citrus fruits and table grapes are exported and European Union is the largest export market (Makhura, 2001). There is also widespread of subsistence farming. It produces maize, wheat vegetables and fruit. Livestock production includes cattle and goat.

5.6 Agricultural activities in Capricorn District

The agricultural sector remains an important industry in the economy of Capricorn district as large tracks of rural areas are mainly held for subsistence livestock farming (CDM, 2011). Capricorn district contribute 9.9 percent of agriculture to the GDP in the province while Sekhukhune district contributes 10 percent. The Capricorn district has a productive commercial farming sector, of 15 percent of the provincial farmers, only 1.1 percent of commercial farmers are from Capricorn district (CDM, 2005). Capricorn district has a diverse farming base which encompasses animal production (broiler, cattle, goats and sheep), maize, potato, tomato, onion, egg and milk.

In the Capricorn district the overwhelming majority of livestock are goats (44 percent), followed by cattle (38 percent), pigs (10 percent) and sheep (9 percent). Nearly all of the goats in the district (98 percent) are communally farmed. It is very clear in the district that goats farming are the most popular form of livestock farming. Most of this livestock is sold for local consumption. Since most of the districts are rural, there is a little use of commercial marketing channels available within district. A large portion of Capricorn district depends on agricultural development and economically on potatoes and tomatoes as the most crops in the district (CDM, 2011).

Maize production comprises the main component in small scale farming mainly because it is a staple food to the majority of people in the district. There is a great potential for commercialisation of crop farming (maize , sorghum , vegetables ect) , livestock farming and introduction of agro – processing initiatives if funding is available , as Mpandeli *et al.*, (2005) and Makhura (2001) emphasised when they said lack of access to credit among small scale famers has a negative effects in agricultural development in most parts of South Africa.

5.7 Agricultural infrastructure in the Limpopo province

One of the major constraints on the growth of agriculture in African countries is high transaction costs (Machete, 2004), largely due to poor agricultural infrastructure. This situation is no different in Limpopo province as large proportion of rural households continues to lack access to basic services (Stilwel and Makhura, 2004). Recent studies indicate that improved infrastructure reduces the cost of transactions for participants in the economy (Makhura *et al.*, 2004) and can improve overall development outcomes and economic competitiveness (DBSA, 2004). It can be further emphasised that poor road conditions, high transport costs and distant markets have been identified as factors that hamper improved market access for farmers in South Africa (Makhura and Mokoena, 2003 ; Mpandeli , 2006).

5.8 Agricultural infrastructure in Sekhukhune District

In Sekhukhune district the problem of water shortage throughout the district is limiting the scale of farming operations and raise costs for farmers due to lack of infrastructure like to install expensive irrigation systems. There is also a problem with the quality of roads as accessibility to agricultural markets is not achievable in most areas (GSDM, 2005). Only two silos and three abattoirs are available in the district, which raises a very serious concern on accessibility and availability of infrastructure. Makhura and Wasike (2003) also found that due to poor social and economic infrastructure in Sekhukhune district it is a challenge for people to acquire agricultural services since access to this service depends on the state of road, transport systems, the distance from the villages to the nearest towns or factories (Makhura, 2001).The District is also faced with huge responsibility of providing water and sanitation to many villages that depended on boreholes and rivers for the past years. Many of these boreholes have dried up while river water is not good for human consumption (GSDM, 2011).

5.9 Agricultural infrastructure in Capricorn District

Capricorn district needs agricultural infrastructure to allow for successful agricultural development to take place especially due to its shortage of primary water sources, backlog and weak infrastructure allocation in rural areas (CDM, 2011). According to Makhura *et al.*, (2004) the development of agricultural infrastructure is one of the prime movers of development. This backlog in infrastructure include agricultural roads, dip tanks, pipelines, storage dams, certain agricultural buildings (silos, abattoirs), fencing, soil conservation works, hand pumps and boreholes. This lack of infrastructure entrenches the problems of chronic poverty and limits the potential of communities to sustain growth, rural livelihoods and social development (Machete, 2004). According to CDM (2011) the state of infrastructure within the district has improved over the past years, with backlogs reduced to 15 percent water, 60 percent sanitation and 15 percent electricity. The district has 2,350km of road network and 163km of the district roads have been tarred.

5.10 Adaptation of farmers to climate change, variability and drought in Limpopo province

As discussed previously, Limpopo province is one of the poorest provinces in South Africa. The majority of people livelihoods are threatened by climate change. For example, drought affected many families and their livestock. As results the shortage of water was identified as the cause of the increased mortality rate of livestock (Letsatsi – Duba, 2009). At district level (Capricorn and Sekhukhune) there is evidence that people are developing adaptation strategies to changing patterns of water availability and the ever – prevalent stress of limited finance, for instance some small scale farmers in Sekhukhune district have set up traditional food seed banks to help maintain food security and at the same time help curb climate change (GSDM, 2011). They also plant traditional crops that require no chemical fertilisers or pesticides and they are drought resistant as well. However, there is also an inability among farmers to understand potential impacts and to take appropriate action before, during, and after particular consequences to minimize negative effects and maintain the ability to respond to changing conditions.

The following comments describe the frustrations people are facing in South Africa about climate change (Sowetan, 2009 and The times, 2012):

"Over the last 10 years, there are more and more strange things happening"

Willem Engelbrecht – Western Cape

"The area already endures extreme weather conditions. The temperature drops to freezing in the winter, and reaches 48 degrees (118 Fahrenheit) in the summer"

Willem Engelbrecht – Western Cape

"Now, summers are hotter and winters, drier. As a result, Engelbrecht has had to adapt his farming techniques"

Willem Engelbrecht – Western Cape

"In the past we used to plough the soil, these days we plough less and we keep material on the soil to act as isolation, basically to preserve the moisture"

Willem Engelbrecht – Western Cape

"We are talking about thousands of square kilometers that are affected. It is not one person alone that can ask the big master for rain, everyone must pray together"

Colyn Scheltema – agriculturalist with 35 years experience.

"This is not about surviving until tomorrow; it's about the future of agriculture and of the farmer who has to help feed South African nation"

Marlon de Jager – Farmer from Eastern Cape

"It is difficult and frustrating to see the investment one has made going down the drain"

France Nemutanzhela – Livestock Farmer – Limpopo province

"The government wants to manage the crisis. They do not want to develop communal farmers"

Andries Madzivhandila – Livestock farmer – Limpopo province

"There is no policy that binds us to compensate communal farmers for their loss of crops or stock"

Dipuo Letsatsi Duba – MEC Agriculture – Limpopo province

The issue of climate change is very frustrating as shown above from the people in different provinces. Climate change is costing communal farmers hundreds of lost livestock due to a lack of grazing and water shortages. Some farmers are now accusing the government of managing crisis instead of implementing preventative measures. They are also accusing government of not providing them with information on how to manage their livestock amid climate change. This is a very serious matter that needs a proactive approach on climate change to give all stakeholders information on how to manage this crisis.

Identification of adaptation strategies is very important especially for poorer and more vulnerable communities. The following adaptation strategies were identified by Molope (2006): (a) Sustainable conservation practices such as reduced, minimum or no till in conjunction with crop rotation and multi-cropping to enhance soil health (b) Use of baseline information already available such as national collections of insects, arachnids, fungi and nematodes to monitor the effect of climate change on biodiversity (c) Continuous drought and heat tolerant crop development by both conventional breeding and biotechnology with emphasis on successful production in marginal areas (d) Decision support systems to assist livestock farmers in handling the effect and consequences of adverse climatic conditions (e) Investigation of the adaptive abilities of indigenous crops; water and rainfall use efficiency technologies to facilitate the principle of more crop per drop (f) Climate change awareness campaigns to reduce the vulnerability of the people and to facilitate the adoption of water use efficiency and conservation ethics (g) Evaluation of the significance of climate change relative to other contextual factors that confront development (h) Development of predictive early warning models, biological control and integrated pest management techniques to ensure adaptive capabilities in view of changing pest and disease dynamics (i) Early warning systems and risk and disaster management are pivotal and should constantly be developed and refined (j) Awareness and adoption of water use efficiency to ensure storage in the soil and as little runoff as possible, and of rainwater harvesting technologies (k) Water use efficiency and sustainability in irrigated agriculture (l) Strengthening the social, economic and environmental resilience of the

poorest and most vulnerable against climate change and variability (m) Investigation and extrapolation of the suitability of crops in different areas in view of biofuel production.

5.11 Summary

- 1) Climate change and climate variability are extremely complex and probably because climate change is progressive. The chapter also highlighted the fact that most farmers case studies indicate that most farmers experience climate variability and change and even the lack of water.
- 2) The chapter also discussed the importance of agricultural infrastructure which forms part of the prime movers for development. Issues that are related to drought, climate variability and change in the study areas were introduced and discussed in this chapter. The challenge on how people adapt to climate change were discussed, where some people in the study areas challenged the government to offer information and adaptation measures against climate change.
- 3) This chapter highlighted the fact that water shortages, socio- economic crisis , weak infrastructure and environmental crisis poses a problem for farmers in both study areas as they don't have resources or means to adapt to climate change. According to Reid *et al.*, (2005) the major challenge to scientists, extensionists and farmers is therefore:
(a) To constantly create awareness of climate change (b) To provide ways of building adaptive capacity (c) To enhance resilience to environmental changes (d) and To see climate risk as one of the major factors shaping the overall multi-stress vulnerability of people and communities.
- 4) Furthermore Molohe (2006) also highlighted key climate change adaptation strategies, namely (a) Sustainable conservation practices such as reduced, minimum or no till in conjunction with crop rotation and multi-cropping to enhance soil health (b) Use of baseline information already available such as national collections of insects, arachnids, fungi and nematodes to monitor the effect of climate change on biodiversity (c) Continuous drought and heat tolerant crop development by both conventional breeding and biotechnology with emphasis on successful production in marginal areas (d) Decision support systems to assist livestock farmers in handling the effect and

consequences of adverse climatic conditions (e) Investigation of the adaptive abilities of indigenous crops; water and rainfall use efficiency technologies to facilitate the principle of more crop per drop (f) Climate change awareness campaigns to reduce the vulnerability of the people and to facilitate the adoption of water use efficiency and conservation ethics (g) Evaluation of the significance of climate change relative to other contextual factors that confront development (h) Development of predictive early warning models, biological control and integrated pest management techniques to ensure adaptive capabilities in view of changing pest and disease dynamics (i) Early warning systems and risk and disaster management are pivotal and should constantly be developed and refined (j) Awareness and adoption of water use efficiency to ensure storage in the soil and as little runoff as possible, and of rainwater harvesting technologies (k) Water use efficiency and sustainability in irrigated agriculture (l) Strengthening the social, economic and environmental resilience of the poorest and most vulnerable against climate change and variability (m) Investigation and extrapolation of the suitability of crops in different areas in view of biofuel production.

CHAPTER 6

Determinants of climate variability and change adaptation strategies of selected Limpopo province farmers

6.1 Introduction

Several studies conducted to examine perceptions of farmers on climate change have shown that farmers had different perceptions on climate change adaptation. It was found by Diggs (1991) that approximately three-quarters of farmers surveyed in the Great Plains had different perceptions in climate variability and change. Another study conducted by Ishaya and Abaje (2008) in Nigeria, revealed that farmers perceived climate change to have occurred over the years due to diverse human activities. According to Mertz *et al.*, (2009) in Sahel, Senegal farmers were aware of the climate variability and identified wind and occasional excess rainfall as the most significant factors that need adaptation.

According to Gbetibouo (2006), 91 percent of farmers in the Limpopo basin perceived changes in temperatures over 20 years to be most significant in climate change. In other African countries, for example it was found that farming with diverse climatic zones have experienced decline in revenues with rise in temperatures (Kurukulasuriya *et al.*, 2006). They further emphasised that revenues from agricultural products sales only increased with increased precipitation while Deressa *et al.*, (2009) indicated that large numbers of farmers' perceived drought and windy weathers to be significant in climate variability and change hence adaptation is needed in those areas. According to Nhemachena and Hassan (2007) in Southern Africa, for example there is a perception that most farmers perceive that long-term temperatures are increasing and the overall perception on long term changes in precipitation is that the region is getting drier and that there are pronounced changes in the timing of rains and frequency of droughts.

Table 6.1: Perceived farmers adaptation strategies in Limpopo province (% of respondents)

Variable	Number of Farmers	Percentage
Plant different varieties		
Yes	105	35
No	195	65
Plant different crops		
Yes	118	39
No	182	61
Crop diversification		
Yes	151	50
No	149	50
Use different planting dates		
Yes	47	15.7
No	253	84
Shorten growing period		
Yes	2	1
No	298	99
Move to different site		
Yes	7	2
No	293	98
Change land size		
Yes	5	2
No	295	98
Change crops to livestock		
Yes	2	1
No	298	99
Change from farming to non farming		
Yes	10	3
No	290	97
Increase irrigation system		
Yes	198	66
No	102	44
Change use of fertilisers, chemicals and pesticides		
Yes	158	53
No	142	47
Increase water conservation		
Yes	17	6
No	283	94
Soil conservation		
Yes	22	7
No	278	93
Use insurance		
Yes	39	13
No	261	87
Use subsidies		
Yes	43	14
No	257	86
Total	300	100

This situation is not different to the selected Limpopo farmers interviewed, who identified their perceived adaptation strategies as seen in Table 6.1. Due to challenges of climate variability and change it was not surprising to notice that 50 percent of the farmers prefer crop diversification as one of their adaptation strategies.

Crop diversification can also serve as insurance against rainfall variability as different crops are affected differently by climate events (Orindi and Eriksen, 2005; Adger *et al.*, 2003). As an adaptation measure to unpredictable rainfall some farmers identified the following strategies as seen in Table 6.1: (a) Use different planting dates (15.7 percent) (b) Plant different crops (39 percent) and (c) Plant different varieties (35 percent). It very clear from the above crop management strategies that majority of farmers did not recognise some of these strategies but there is a tendency that some farmers perceived those crop management strategies which is encouraging.

The majority of farmers perceive that soil fertility management may help them against climate variability and change. As seen in Table 6.1, almost 53 percent of farmers think change use of fertilisers, chemicals and pesticides will improve their adaptation capacity against climate change. According to IPCC (2011), chemicals, fertilisers and pesticides can improve crop yields tremendously but can also be costly to the environment. That is why some farmers in Limpopo province are applying organic fertilisers such as those resulting from composting. They believe that by emphasizing on organic farming carbon is stored in soils and contribute significantly to the reduction of greenhouse gas emissions. This is true as carbon sequestration in soil has been recognised by Intergovernmental Panel on Climate Change and European Union as one of the possible measures to mitigate greenhouse gases.

Water management strategies e.g. increased irrigation system was the most perceived strategy compared to other adaptation strategies. This is not surprising given the socio-economic challenges in Sekhukhune and Capricorn districts. The majority of farmers believe irrigation systems could make them adapt to climate variability and change. At least 60 percent of farmers prefer improved irrigation systems. The use of irrigation has the potential to improve agricultural productivity through supplementing rainwater during dry spells and lengthening the growing season (Baethgen *et al.*, 2003, Orindi and Eriksen, 2005). It is important to note that irrigation water is also subject to impacts from climate change. Use of irrigation technologies need to be accompanied by other crop management practices such as use of crops that can use water more efficiently. Important management practices that can be used include: (a) Efficient management of irrigation systems (b) Growing crops that require less water and (c) Optimizing of irrigation scheduling and other management techniques that help reduce wastage (Loë *et al.*, 2001).

Other perceived strategies were mentioned by few farmers to deal with climate variability and change like: (1) Use insurance (2) Use subsidies (3) Change land size (4) Change crops to livestock (5) Shorten growing period were not popular among most of the farmers.

6.2 Perceived barriers to adaptation in Limpopo province

Table 6.2: A comprehensive list of barriers identified in Capricorn and Sekhukhune Districts

Barriers	Suggestions for enabling environment
Lack of education and financial resources	Government support is needed
Lack of knowledge about climate change issues	Training must be provided by government through extension services
Lack of equipments i.e. tractors	Government intervention in providing of equipments is needed
Lack of production inputs	Government intervention in providing of production inputs is needed
Lack of skilled extension officers	Government should offer relevant training to their extension officers
Lack of water / irrigation system	Government should prioritise water issues as this is already affecting farmers especially in Sekhukhune
Poor dissemination of information about climate change	Farmers should use other sources of information and extension officers should also provide information
Lack of new technology	Government support; international cooperation; international funding is key to address this barrier

The study also requested farmers about their perceived barriers to using various adaptation measures as indicated in Table 6.2. The results indicate that: (a) Lack of education (b) Financial resources (c) Information concerning climate change (short term variations and long-term climate change (d) Knowledge regarding climate change (e) Lack of equipments (f) Lack of water and production inputs are important constraints for most farmers in both districts. Since most of farmers were operating under resource limitations, lack of new technology and lack of skilled extension officers were some of their barriers for adaptation.

6.3 Climate change adaptation measures used by some farmers in Limpopo Province

This section presents various adaptation strategies being used by some Limpopo Province farmers in response to changing climatic conditions based on the survey. The adaptation strategies are grouped into Colds, Heat, Frost, Abnormal Wind and Hail, Extension Support, Drought, Rainfall, Temperature and Nematodes, Insecticides and Worms.

(a) Colds, Heat, Frost, Abnormal Wind and Hail

Some farmers with resources are using the Dacom system, which is an environmental tool that foresees incoming weather change like frost, hot days, abnormal winds and colds. Farmers also apply 8mm of water at least a night before frost to avoid excessive damage.



Picture 6.1 Nets / shades as adaptation measure against cold and heat conditions

Farmers also put nets around their crops to protect against colds, heat and frost as seen in picture 6.1. Tyre burning is also popular among resource poor farmers to protect their crops against cold. This burning of tyres serves as a blanket for crops like tomatoes during cold season. It was also noted during the survey that the majority of farmers are practicing the crop diversification system which forms part of the risk aversion strategy.

Some farmers prefer to plant cotton during hot weather because of its resistance to hot weather. The selection of crops which are not damaged against colds, heat, and frost also serve as other farmers' adaptation measure which is normally being practiced in the province. Those farmers with water adapt by irrigating crops the following day after weather damage. For farmers that can access water are at least better than the ones that do not have water. This has proven positive in some instances. Fertilisers are also applied after cold / hail/frost damage to revive production.



Picture 6.2: Wood serving as adaptation measure against abnormal winds

Wood also serves as adaptation measure especially for tomatoes against abnormal wind as seen in picture 6.2. In some instances Germ tomatoes is preferred as it can grow well under cold weather conditions. Reducing of planting space is also used by some resource poor farmers against cold weather. This is used mostly by cabbage and spinach farmers, who believe that by reducing planting space, crops serve as blankets to each other during cold weather and this method is working very well.

(b) Extension Support Services

Big companies like Lonmin in Limpopo Province offered farmers with extension services. These farmers are also offered opportunity to attend skills development workshop regarding climate and agricultural issues. Government is also playing an important role in

providing farmers with seeds, fertilisers, pesticides, skills training but they don't offer this to all affected farmers and some of these farmers needs support like labour, packaging, financial and harvesting assistance from government. Joint ventures / partnerships are also a good adaptation measure to deal with climate change. Here resource poor farmers partnered with skilled white commercial farmers in order to receive skill transfer, climate advisory information, technical, markets availability and infrastructural assistance. Some of the commercial farmers mentor and plough back their adaptation measures to resource poor farmers. Some commercial farmers even went extra mile by registering group of farmers at different tertiary institutions such as university of technology.

(c) Rainfall

Dacom system is used to foresee incoming weather change like low and high rainfall in some parts of Limpopo province. The use of cultivars that is resistance to high/low rainfall is used by some well resourced farmers in Limpopo province. Some farmers are using Dacom system to change planting dates in case of unexpected weather patterns. Through this Dacom system farmers can harvest too early not to lose product quality and they can also shift harvesting through day and night harvesting. But this is labour intensive since all products should be harvested before expected damage. Farmers also use clouds as an indicator for possible rainfall. When clouds are clustered and dark, for example, farmers know that they will have rain within a short period of time. Wind direction is also used by some farmers as an indicator for possible rainfall. They believe that when wind came from the western side they would receive rain within 12 hours and this form part of indigenous or traditional knowledge system.

(d) Drought

Farmers in the area also developed drought – coping mechanisms and longer term research on the ecological, economical and social effects of drought. Some of the conservation practices used includes the following: Minimum tillage, zero tillage, soil cover ect.



Picture 6.3: Minimum tillage practice by farmers in Limpopo Province

Source: ARC-ISCW (2007)

As shown in picture 6.3 minimum tillage is the low-impact system replacing ploughing which enhances carbon retention in soil. Minimum tillage is considered to be best conservation agricultural management practice within the agricultural sector across the continent. The aim of this practice was to minimise soil disturbance and also retaining moisture throughout. This practice it also provides a wet season cover crop to protect the beds from slumping. Some of the advantages of minimum tillage includes: (a) Better soil structure, (b) Reduced soil loss and (c) Reduced fuel costs.



Picture 6.4: Water harvesting and optimization practice by farmers in Limpopo Province and other parts of the country

Source: ARC- ISCW (2007)

Picture 6.4 shows how rain water harvesting is practiced in the province. Rain water harvesting as indicated in picture 6.4 is when water is collected from the ground and this has achieved excellent results especial in some dry parts of Limpopo province. The primary reason to use this practice is to store available rainwater during the wet season and also to use the water for crop irrigation in the dry season. This technique is also being practice in the SADC region due to its efficiency. This technique was adopted by ARC-ISW in the Free State Province 13 years ago.



Picture 6.5: Multi cropping and rotation practice by farmers in Limpopo Province and other parts of the country.

Source: ARC –ISCW (2007)

Crop rotation and multi cropping has become very popular in some dry parts of Limpopo province. As indicated in picture 6.5, crop rotation contributes to diversification of crop species and decreases diseases and pests attack. Greater nutrient utilization, less use of pesticides, and improved soil quality may reduce the overall environmental impact of crop production. The other preferred practice is multi cropping, which is the practice of growing two or more crops in the same space or piece of land during a single growing season and can reduce the risk of total loss from drought or pests.



Picture 6.6: Mulching system practiced by framers in Limpopo Province and other parts of the country. *Source: ARC-ISCW (2007)*

As shown in picture 6.6, mulching is essential to the survival of crops during drought periods. Mulch will reduce the amount of water that evaporates from the soil. Mulching improves the quality of the soil by breaking up clay and allowing better water and air movement through the soil.

The benefits of this practice includes conserving moisture, slowing flood waters, lessening the need for pesticides, healthier crops and smothering weeds.



Picture 6.7: Environment monitoring tool – rain gauge

Due to drought in the province some farmers established ventilation points in the soil for water to evaporate. A rain gauge as seen in picture 6.7 is also used by some farmers to measure the amount of rainfall. The data from rain gauges are especially important for farming in order to make decisions about crop planting. In order to adapt against drought, some farmers have water all the time as a measure of adaptation. They have good irrigation systems like centre pivots, drips and dams. Latest machines to take water to the fields are also available while some have boreholes and water underground. However, the maintenance of the centre pivots is a serious challenge to majority of these farmers.

(e) Temperature

The Dacom system is being used by farmers with resources as adaptation measure against increased temperature. This basically helps farmers to monitor temperature levels in the soils. They also have fertilisers and chemicals to use against unacceptable temperature levels. Some resource poor farmers rely on friends, fellow farmers to establish temperature levels. However, the challenge with this kind of approach is on the interpretation of the information.

(f) Nematodes, Insecticides and Worms

The well resourced farmers in Limpopo province are using chemical agents from reputable agrochem companies for dealing with nematodes, insecticides and worms. They use nemamate as a chemical to prevent nematodes infestation and if damage has already occurred they use nemacur. Most farmers emphasised the reading of recommendation as very important. Resource poor farmers plant onions alongside other crops to kill insects and worms. In this way onions kill insects and worms through its smell. This adaptation measure is very effective and positive results are achieved or being witnessed across the districts.

6.4 Summary

- 1) This chapter begins by presenting perceived adaptation strategies of selected Limpopo province farmers. Some of their farmers perceived adaptation strategies included: (a) Soil management strategies (b) Water management strategies and (c) Others like use of subsidies and use of insurance. The results indicated that farmers are aware that Limpopo Province is getting warmer and drier with increased frequency of droughts and changes in the timing of rains, that is why some of these farmers identified some barriers to adapt to climate variability and change. Barriers such as (a) Lack of information (b) Lack of government support (c) Lack of education and skill were discussed in this chapter. Addressing these issues can significantly help farmers to tailor their management practices to warmer and drier conditions. Adaptation is therefore critical and of huge concern in Limpopo province because the majority of poor resource farmers in the province have low adaptive capacity and also lack or limited finance and technology.
- 2) Important adaptation options being used by farmers were also discussed in this chapter. This included different adaptation measures against colds, heat, frost, abnormal wind, hail, lack of extension support, nematodes, insecticides, worms, temperature and rainfall. As mentioned earlier, Limpopo province farmers have low

capacity to adapt, it was interesting to observe that some of these farmers are using indigenous coping strategies like burning of tryes to adapt. So supporting these coping strategies of local farmers will help increase the adoption of adaptation measures thus bringing great benefits to the majority of these vulnerable farmers in Limpopo province.

CHAPTER 7

7.1 Conclusions and Recommendations

According to IPCC (2007) the scientific community widely agreed that climate variability and change is already a reality. Over the past century, surface temperatures have risen, and associated impacts on physical and biological systems are increasingly being observed. In areas such as Limpopo Province climate variability and change will bring about gradual shifts such as sea level rise, movement of climatic zones due to increased temperatures, and changes in precipitation patterns. Climate variability and change is also likely to increase the frequency and magnitude of extreme weather events such as droughts, floods and storms. Limpopo Province has already experienced some of these weather events especially in the form of floods as was the case in January 2000, as well as early in the year (January 2012), where floods destroyed crops, and infrastructure, and affected the harvest. While there is uncertainty in the projections with regard to the exact magnitude, rate and regional patterns of climate variability and change, its consequences will change the fates of generations to come.

In addition, the nature of the climate impact will be affected by the agriculture sector's own growth since its emissions also contribute to climate variability and change. As agreed by many scientists, climate change is mainly driven by the emission of greenhouse gases, such as carbon dioxide, methane and nitrous oxide (IPCC, 2007). Among all 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 greenhouse gas emissions, primarily as a result of the over use of fertilizers, land clearance or deforestation, soil degradation, and intensive animal farming.

According to IPCC (2007) poor countries and communities are some of the most vulnerable to impacts of future climate change. Most of these communities have arguably lower capacity to adapt to change and have insufficient resources to mitigate the impacts associated with global environmental change (Smith *et al.*, 2001).

Therefore, there is a need for urgent adaptation strategies in the agricultural sector and is required to the changes in climate especially in Africa where millions of people depend on it for survival. According to UNFCCC (2008) Africa will be hit hardest by climate change as larger areas could be stricken by yield decreases of over 50 percent by the year 2020 as a result of increasingly hotter and drier climate. This will threaten food security and people's livelihoods in most parts of Africa.

It is against this background that to be able to adapt to climate variability and change it is essential for development partners to deliver on their commitments to support African countries to adapt to the unavoidable impact of climate change which includes scaling up efforts in order to:

- a. Improve and increase access to climate data,
- b. Invest and transfer technologies for adaptation in key sectors,
- c. Develop and implement best practice guidelines for screening and assessing climate change risk in their development projects and programs in climate sensitive sectors,
- d. Mainstream climate factors into development planning and implementation, and
- e. Provide significant additional investment in disaster prevention.

7.2 Understanding the impacts of climate variability and change

The summary in **chapter 1** with reference to understanding the impacts of climate variability and change on agricultural production in Limpopo province is that climate variability and change impacts vary from area to area due to agro ecological zones and agricultural setup. It is also assumed that the majority of farmers in both the Capricorn and Sekhukhune districts are using different coping and adaptation strategies in order to increase their crop yields. To further understand the impact of climate variability and change in Limpopo province, two study areas were visited and farmers were interviewed. The visits gave the researcher first hand information about impacts of climate variability and change in the study areas. As mentioned in the preceding chapters, female farmers were mostly affected by climate variability and change in Limpopo province since they were in the majority in the farming business.

Various studies also confirm the role of gender in climate variability and change adaptation. According to Bayard *et al.*, (2007) female farmers are more likely to adopt natural resource management and conservation practices. It was also emphasized by Burton *et al.*, (1999) that female farmers are indeed important in the choice of agricultural practices to adopt, particularly in regard to conservation or sustainable technology. According to Nhemachena and Hassan (2007) the possible reason for female to adapt is that in most rural smallholder farming communities, men are more often based in towns, and much of the agricultural work is done by women. Therefore, women have more farming experience and information on various management practices and how to change them, based on available information (Anim, 1999). It was also noted that it is women who spend most of their time in the field than men (StatsSA, 2007).

The response of farmers to climate variability and change further contributed to the understanding of climate variability and change impact in Limpopo province. The education levels of most farmers were very low, with majority completed only primary education. It was understood that this situation will further make it difficult for farmers to adapt to climate variability and change as Maddison (2007) emphasised 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.

The majority of the farmers indicated that climate variability and change will have negative consequences on agricultural production. For example, the study showed that the majority of farmers rely on only one source of information such as radios regarding climate variability and change. This is because most farmers are in rural areas and access to other sources of information remains a challenge. Access to extension services remains a problem in Limpopo province, since most extension officers are unavailable to some farmers and it is important to note that without extension services it is understood that farmers will find it difficult to obtain relevant agricultural training and information as Adesina and Forson (1995) and Mpandeli (2006) hypothesized that access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills.

It was also noted that farmers will remain vulnerable to climate variability and change in Limpopo province because of the lack of means support such as climate advisory information, lack of access to technology, limited finance. The understanding is that due to lack of credit, insurance, farmer support, government support and subsidies, farmers' ability to get the necessary resources and technology to adapt to climate variability and change will be limited. This is true as Kandlinkar and Risbey (2000); Makhura (2001) and Mpandeli (2006) emphasised that since most farmers in Africa are operating under resource limitations: (a) lack of credit, (b) subsidies and (c) insurance, will accelerate farmers' failure to meet transaction costs necessary to acquire adaptation measures as a result of unexpected weather patterns.

7.3 Assessing the impacts of climate variability and change

As part of assessing climate variability and change theoretical and empirical studies relating to climate change adaptation were discussed in **Chapter 2**. Climate change is fast pushing the poorest and most marginalized communities beyond their capacity to respond. **Chapter 2** draws on situations from around the world based on lessons learned and case studies. It sets out what is needed to enable people living in poverty to adapt to climate change, as well as a range of interventions that are available. This study brings together experience in the role of institutional arrangements in addressing climate change. Agricultural setup across the globe is also presented in this chapter which suggested that countries are facing the highest reductions in agricultural potential due to climate variability and change.

Chapter 2 also looked at various climate change adaptation strategies in other sectors such as water resource, biodiversity, as well as the health sector, which are expected to develop greater capacity to manage risk, uncertain conditions and therefore to adapt more readily to new and different conditions. The other sector discussed was biodiversity and ecosystems where climate change is expected to cause major shifts of many species. The last sector discussed was health, which if it cannot adapt will lead to weak and unhealthy labour force resulting in few participation in food production and this will affect the Limpopo Province as most of these farmers rely on labour intensive system. This has illustrated that climate change adaptation is possible in countries whereby there is strong financial support, good institutions, good governance and policies available.

This was also supported by United Nations Framework Convention on Climate Change where it was emphasised that future decisions about climate change must assist developing countries in a streamlined, innovative and transparent way, with transfer of knowledge, technology and financial resources to adapt at all levels and all sectors.

To assess climate variability and change further, **Chapter 2** provided a literature review of the impact of climate variability and change in the agricultural sector. In fact, it has documented some of the likely impacts of climate change on International, continental, regional, national and provincial agricultural setup. This chapter has shown that climate change will have a significant impact on agriculture, primarily through affecting livestock production, which represents 40 percent of agricultural production worldwide and provides livelihoods and food security to one billion people. Agricultural crop yields and prices will also be affected by changing weather patterns thus resulting in food insecurity especially for those farmers with advanced technology and good modern agricultural practices. Rain-fed farmers are predicted to be more adversely affected than irrigated farmers, and impacts on income also vary widely by region and by season. All this will have a serious impact on food security, in which Africa will be hit hardest since it has low capacity to adapt to changing weather patterns.

Government will have to make a great effort in response to climate change. The government must promote policies and invest funds in adaptation. In addition, it must focus regulatory and legislative efforts, as well as investment activities. First the government must seek to support the development of new technologies and identify additional measures to deal with future climate change. Second, the government needs to reform its extension system to improve the access to knowledge by local people. Third, the government needs to enhance institutional awareness, capacity and cooperation. Finally working with farmers by setting an enabling policy environment is the number one role of governments. The study highlighted the impact of climate change on various sectors including water resources, forestry, natural ecosystem human health, infrastructure and coastal zones. A worrying situation is reviewed globally in this chapter and it can be concluded that climate change and variability is affecting every sector and it needs urgent attention.

In order to assess the impacts of climate variability and change on agricultural production, it is very important to highlight the socio economic and biophysical factors in Limpopo province. In **chapter 3** the socio- economic and biophysical contexts for the research undertaken was provided. It should be acknowledged that Limpopo province offers a range of opportunities as well as challenges for farmers as indicated in **chapter 3**. Limpopo province is characterised by poor and highly variable in distribution (**Figure 3.1**). According to Letsatsi –Duba (2009) the occurrence of drought in 2009 was the worst ever in Limpopo province. This is evident in **Figure 3.1** which showed rainfall averaged to 282,1mm annually in 2009, nearly dropping below threshold for rainfall agriculture. There were also good rainfall years in Limpopo province as shown in **Figure 3.1** especially 1980, 1981, 2000 and 2001 respectively. In general it can be concluded that rainfall distribution has indeed changed in the past 30 years in Limpopo province and information on rainfall amount and variability is important for improved decisions concerning crops choice and crop variety to grow.

Figure 3.2 indicated that the rainfall outlook for Sekhukhune and Capricorn districts looks very bad and this can be contributed to change of weather pattern that is occurring in the two districts. The results indicated that the probability of both districts in receiving below normal rainfall is 50 percent for May – July 2012. It is evident from **Figure 3.2** that there is no / little probability for both districts to receive above normal rainfall. This will create lot of problems for farmers and it will require the use of adaptation measures like using of drip irrigation which saves water, irrigating during cool conditions to avoid evapotranspiration and to adhere to the water restrictions issued all the time. **Figure 3.3** showed change in rainfall patterns in Limpopo province occurring throughout the year and it emphasise the need for farmers to be vigilant to adapt to changing weather patterns.

By assessing the rainfall distribution in Limpopo province, it is very evident that the impact of periods of lower rainfall has particular negative effects on the agricultural sector, According to Mpandeli (2005) low rainfall will lead to: (a) Decreased agricultural activities, (b) Loss of livestock, (c) Shortage of drinking water, (d) Low yields and (e) Vegetation impacts may vary from district to district.

As indicated in **Figure 3.4**, Sekhukhune district temperature has been changing overtime and showed high temperature levels. These results are consistent with Hugues and Balling

(1996) who reported that there is an increase in average temperatures per decade over the period 1960 – 1990 and these trends were significant for both non urban and urban stations. This result also explains why Sekhukhune district is frequented by droughts and poor rainfall thus affecting agricultural production.

Capricorn district average temperatures trends shows high levels as showed in **Figure 3.5**. This situation is supported by Kruger and Shongwe (2004) who found that there was a significant increase in temperature between 1960 – 2003 for Polokwane, Bela Bela and Musina stations in the Limpopo province. This condition has lead to occurrence of droughts around Capricorn district and put most farmers vulnerable to climate variability and change.

The results in **Figure 3.6** showed that average temperatures in Sekhukhune and Capricorn districts for June – August 2012 is high. The results showed enhanced probabilities of 50 percent for above normal maximum temperatures in the entire Limpopo province. This is again raising a very serious about temperature trends in Limpopo province which will increase poor rainfall patterns and accelerate frequency of droughts.

Descriptive statistics was used to assess climate variability and change impact on agricultural production (**Chapter 4**). Results indicate that farmers are aware that Limpopo province is getting warmer and drier with increased frequency of droughts and changes in the timing of rains (**Figure 4.9 and Figure 4.10**). The implication is that farmers need to adjust their management practices to ensure that they make efficient use of the limited rainfall and water resources for food production and other needs. Farmers identified: (a) Lack of information about climate variability and change, (b) Lack of information through extension services, (c) Poor adaptation capacity and (d) Lack of source of information as important constraints (**Figure 4.6, Figure 4.7 and Figure 4.11**). Addressing these issues can significantly help farmers to tailor their management practices to warmer and drier conditions.

Statistical analysis which is used to determine level of association between variables confirmed that being full time farmer, sex of farmer, information on climate change, information received through extension services and adaptation to climate change are

some of the important determinants of agricultural production, unemployment , food scarcity and food prices (Table 4.7, Table 4.8, Table 4.9 and Table 4.10).

7.4 Identification of adaptation measures that reduces the impacts of climate variability and change

Chapter 5 indicated that at district level (Capricorn and Sekhukhune), there is evidence that people are developing adaptation strategies to changing patterns of water availability and the ever – prevalent stress of limited finance, for instance some small scale farmers in Sekhukhune district have set up traditional food seed banks to help maintain food security and at the same time help curb climate change (GSDM, 2011). They also plant traditional crops that require no chemical fertilisers or pesticides and they are drought resistant as well. However, there is also an inability among farmers to understand potential impacts and to take appropriate action before, during, and after particular consequences to minimize negative effects and maintain the ability to respond to changing conditions. Some of the perceived adaptation strategies of selected Limpopo province farmers were identified in **Chapter 6**. They included: (a) Soil management strategies, (b) Water management strategies, (c) Use of subsidies and (d) Use of insurance as shown in **Table 6.1**. **Chapter 6** also identified perceived farmers barriers to climate variability and change adaptation, which included: (a) Lack of education, (b) Financial resources, (c) Information concerning climate change (short term variations and long-term climate change, (d) Knowledge regarding climate change, (e) Lack of equipments, (f) Lack of water and (g) Production inputs are important constraints for most farmers. Different adaptation strategies were used as seen in **Picture 6.1, Picture 6.2, Picture 6.3, Picture 6.4, Picture 6.5, Picture 6.6 and Picture 6.7**.

7.5 Recommendations

A number of recommendations emerge from this thesis and these recommendations could be considered by Limpopo province department of agriculture and other key stakeholders that are dealing with climate change issues and may require further research.

7.5.1 Information about climate change

Farmers need adequate knowledge about the importance of climate change in order for these farmers to be able to adapt effectively as discussed in previous chapters. So, transfer of climate knowledge to support vulnerability and adaptation measures are advocated in this regard. To accomplish these farmers should use different information sources like the media both printing and the electronic, research institutions such as the Agricultural Research Council, Agricultural Extension Services and Civil Societies like NGOs for the dissemination of the climate change, climate advisory information across various farmers in the province.

Government policies should also address the importance of early warning systems and information distribution systems as another mechanisms of adapting to climate variability and change across sectors including the agricultural sector. Information on climate change impacts should also be translated from the scientific research to a simple language in order for various end users to understand that information. The government through extension services and support should also empower farming communities so that they can participate in assessments and feed in their knowledge to provide useful climate information.

7.5.2 Adaptation to climate change

The extreme weather patterns caused by climate variability and change in Limpopo province have impacted the farming communities severely for the past several years. The majority of these farmers have limited adaptive capacity, finance, technology to respond towards climate change challenges. These farming communities must use identified adaptation measures in this study and use the resources available to them to tackle climate variability and change. Adaptation to climate variability and change must become an important policy priority to the government and effectively be mainstreamed into national, provincial, local and sectoral development agendas as outlined in the recently published and approved National Climate Change Response Policy in October 2011.

7.5.3 Information dissemination through extension services

The role of agricultural extension officers should be further explained to the farming communities in Limpopo province. This must include Agricultural extension officers role in encouraging farmers to adopt new technologies, improved methods of farming, using a variety of methods to reach farmers i.e. organizing study groups for farmers, farmer days, demonstrations, lectures etc, as well as informing the media about farmers challenges. Designing policies that aim to improve role of extension services in communities have great potential to improve farmer adaptation to changes in climate as discussed in previous chapters. Government policies need to support the training of extension officers so that they give farming communities relevant information about climate change adaptation.

7.5.4 Drought

Drought is a recurring problem in Limpopo province as seen in **chapter 5**. According to Mpandeli (2005) in times of drought, different coping strategies should be gathered, understood and shared amongst a range of end users e.g. either by the National Agro Meteorological Committee, research institutions such as Agricultural Research Council and the South African Weather Service. Limpopo farmers should also be encouraged to use drought-resistant cultivars during drought periods.

7.5.5 Indigenous coping strategies

Indigenous coping strategies should play an integral role in building climate resilience as seen in **chapter 6**. From the results it is evident that existing adaptive local practices can be harnessed and tailored to ensure communities are able to reduce their vulnerability to climate variability and change. Indigenous coping strategies must not only be sought and recognized, but also integrated with conventional science if farmers are planning to tackle climate change challenges in the agricultural sector.

7.5.6 Crop diversification

Farmers should be encouraged and enabled to use crop diversification as adaptation coping strategy. This is a common practice to find many crop species on the same piece of land to guard against crop failure in times of adverse climatic conditions.

The results of this research are potentially valuable to the agricultural sector considering the international and local debate and interest in order to counter act the impact of both the climate variability and change. Government will have to make a great effort in response to climate change. The government must promote policies and invest funds in adaptation. In addition, it must focus regulatory and legislative efforts, as well as investment activities. (a) First the government must seek to support the development of new technologies and identify additional measures to deal with future climate change. Second (b) The government needs to reform its extension system to improve the access to knowledge by local people. Third (c) The government needs to enhance institutional awareness, capacity and cooperation. Finally working with farmers by setting an enabling policy environment is the number one role of governments.

Designing policies that aim to improve these factors for smallholder farming systems have great potential to improve farmer adaptation to changes in climate. Government policies need to support research and development that develops and diffuses the appropriate technologies to help farmers adapt to changes in climatic conditions. Government responsibilities should usually be through policy measures to enhance the adaptive capacity of agricultural systems.

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APPENDIX A : QUESTIONNAIRE

CLIMATE CHANGE & AGRICULTURAL PRODUCTION IN LIMPOPO PROVINCE: IMPACT & ADAPTATION OPTIONS.

INSTRUCTIONS TO INTERVIEWERS

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

Date of interview:

Number:

Area

District Municipality	
Local Municipality	
Number of Years Farming in the area	

A.1 COMPOSITION AND CHARACTERISTICS OF FARM

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

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

Codes for employment status:		Codes for education:		Codes for Relationship to Farmer	
Working full-time	1	No formal schooling	1	Father	1
Working part-time	2	Some primary education	2	Mother	2
Casual/piece jobs	3	Primary education completed	3	Brother	3
Unemployed	4	Some secondary school education	4	Sister	4
Pre-school	5	Secondary school education completed	5	Uncle	5
Student (at school or further education)	6	Post secondary college education	6	Other (specify)	6
Pensioner	7	Certificates / Short courses	7		
Housewife taking care of home full-time	8	University degree	8		
		Refused	9		

A.2 CROPS CULTIVATED

What crops do you plant?

Indicate by making a tick whether the crops are planted for:

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

A.3 LAND CHARACTERISTICS

1. Type of Farm

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

Tribal Farm	-5
Other (please specify)	-7

2. Who manages the farm?

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

3. Who owns the farm?

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

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

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

B.1 CLIMATE CHANGE ISSUES

1. Do you receive information on climate change?

Yes	1
No	2

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

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

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

Yes	1
No	2

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

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

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

Formal credit	-1
Insurance	-2
Farmer to Farmer extension	-3
Relatives	-4
Subsidies	-5
Other (specify)	-6

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

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

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

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

8. Have you ever experience the following lately?

Drought	-1
Abnormal Wind	-2
Floods	-3
Frost	-4
Cold	-5
Other (specify)	-6

9. How has climate change affected your crops?

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

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

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

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

Reducing fertility of land	-1
Reduced crop yields	-2
Increased crops diseases	-3
Reduced livestock production	-4
Other , specify	-5

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

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

B.2 ADAPTATION MEASURES

1. Did you adapt to climate change

Yes	1
No	2

2. What are your perceived adaptations options?

Plant Different crops	1
Plant different varieties	2
Crop diversification	3
Use different planting dates	4
Shorten length of growing period	5
Move to different site	6
Change amount of land	7
Change crops to livestock	8
Change from farming to non farming	9
Increase irrigation	10
Change use of chemicals , fertilisers and pesticides	11
Increase water conservation	12

Soil conservation	13
Use Insurance	14
Use subsidies	15
Prayer	16
Other adaptation	17
No adaptation	18

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

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

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

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

APPENDIX B: CONSENT FORM

CONSENT FORM

TITLE OF RESEARCH PROJECT

Dear Mr/Mrs/Miss/Ms _____

Date...../...../20...

NATURE AND PURPOSE OF THE STUDY

RESEARCH PROCESS

- 1.
- 2.
- 3.
- 4.
- 5.
6. continue adding information as required

NOTIFICATION THAT PHOTOGRAPHIC MATERIAL, TAPE RECORDINGS, ETC WILL BE REQUIRED

CONFIDENTIALITY

WITHDRAWAL CLAUSE

POTENTIAL BENEFITS OF THE STUDY

INFORMATION (contact information of your supervisor)

CONSENT

I, the undersigned, (Full name) have read the above information relating to the project and have also heard the verbal version, and

declare that I understand it. I have been afforded the opportunity to discuss relevant aspects of the project with the project leader, and hereby declare that I agree voluntarily to participate in the project.

I indemnify the university and any employee or student of the university against any liability that I may incur during the course of the project.

I further undertake to make no claim against the university in respect of damages to my person or reputation that may be incurred as a result of the project/trial or through the fault of other participants, unless resulting from negligence on the part of the university, its employees or students.

I have received a signed copy of this consent form.

Signature of participant:

Signed at on

WITNESSES

1

.....

APPENDIX C: UNISA ETHICS APPLICATION OUTCOME

Ref. Nr.: 2011/CAES/025

To the student:

Mr Phokele Maponya
 Department of Environmental Sciences
 College of Agriculture and Environmental Sciences

Student nr: 35799757

Dear Mr Maponya

Request for Ethical approval for the following research project:

Climate change and agricultural crop production in Limpopo province: Impact and Adaptation options

The application for ethical clearance in respect of the above mentioned research has been reviewed by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa.

The committee is pleased to inform you that ethical clearance has been granted for the research set out in the Ethics application (Ref. Nr.: 2011/CAES/025) submitted and additional documents attached to the application.

Please be advised that the committee needs to be informed should any part of the research methodology as outlined in the Ethics application (Ref. Nr.: 2011/CAES/025), change in any way. Should that be the case, a new application, for the amendments, needs to be submitted to the Ethics Review Committee for review.

We trust that sampling, data gathering and processing of the relevant data will be undertaken in a manner that is respectful of the rights and integrity of all participants, as stipulated in the UNISA Research Ethics Policy.

The Ethics Committee wishes you all the best with this research undertaking.

Kind regards,



Prof E Kempen
CAES Ethics Review Committee Chair

APPENDIX D: LETTER FROM HEAD OF DEPARTMENT

Limpopo Department of Agriculture



LIMPOPO

PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF AGRICULTURE OFFICE OF THE HOD

File No: 12/R
Enquiries: Dr.B.M Petja
Date: 13 September 2010

Mr. P.I. Maponya
Ph.D candidate
Department of Environmental Science
University of South Africa
Florida Campus

Request to conduct a PhD Research Studies in the Limpopo Province

Your request for conducting a Research Project for PhD studies refers.

Kindly take note that your request to conduct the research on your chosen topic here in the Limpopo Province has been accepted under the following conditions from the Sub-branch Research Services.

- You will liaise with the Specialist Researcher in the Adaptive Research and Innovation Division regarding activities and challenges related to your research while in the province and assistance you may require from the department.
- You will also be required to update the division in terms of the progress report of your research work.
- Upon completion of your study you are requested to provide a copy of your final report for the departmental records and reference.

Depending on the time and availability, the department may provide you with the opportunity to engage with resident climate change experts in the division.

Contact details for the Adaptive Research and Innovation Division (Specialist Researcher):

Name: Dr. Brilliant M. Petja, **Tel** 015 2943208, **Mobile** 082 727 9098.

Sincerely,

Professor AE Nesamvuni
Head of Department

67/69 Biccard Street, POLOKWANE, 0700, Private Bag X9487, Polokwane, 0700
Tel: (015) 294 3135 Fax: (015) 294 4512 Website: <http://www.lida.gov.za>

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APPENDIX E: PAPER PRESENTATION

International Conference on Climate Change 2012: Impact and Responses

12 – 13 July 2012

University of Washington, USA

APPENDIX F: PAPER ACCEPTED

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Climate Change and Agricultural Production in South Africa: Impacts and Adaptation options

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Abstract

The primary aim of the paper was to identify the impacts and adaptation options of climate variability and change on agricultural production in Limpopo province. The following objectives were identified: to understand the impacts of climate variability and change on agricultural production in Limpopo province; to assess the impacts of climate variability and change on agricultural production in Limpopo province and to identify adaptation measures that reduces the impacts of climate variability and change on agricultural production in Limpopo province. A representative sample of 300 farmers aged 16 – 65+ years (46 percent males and 54 percent females) participated in the study. The study involved Sekhukhune and Capricorn districts, with 56 percent farmers in Capricorn and 44 percent in Sekhukhune district. The following 11 local municipalities were visited: Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane, and Molemole. Statistics was used to determine climate variability and change impact on agricultural production. Results indicate that farmers are aware that Limpopo province is getting warmer and drier with increased frequency of droughts, changes in the timing of rains, observed trends of temperature and precipitation. This paper also confirmed that being full time farmer, gender, information on climate change, information received through extension services and adaptation to climate change are some of the important determinants of agricultural production, food scarcity and unemployment. The paper also presented perceived adaptation strategies of selected Limpopo province farmers. Some of their perceived adaptation strategies included: (a) soil management strategies, (b) water management strategies and (c) others like use of subsidies and use of insurance. Other important adaptation options being used by farmers were also discussed in this paper including different adaptation measures against colds, heat, frost, abnormal wind, hail, lack of extension support, nematodes, insecticides, worms, temperature and rainfall. The results of this paper are potentially valuable to the agricultural sector considering the threats that climate change poses across climate sensitive sectors

Keywords: climate variability, climate change, agricultural production, Limpopo, South Africa

1. Introduction

Climate change directly affects agricultural production, as agriculture sector is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impact of global climate change (Parry et al., 1999). According to UNEP (2008) “humanity is living beyond its environmental means and running up ecological debts that future generations will be unable to repay as a result of global climate change”. Agricultural production remains the main source of livelihood for rural communities in Africa, providing employment to more than 60 percent of the population and contributing about 30 percent of gross domestic product (Nhemachena & Hássan, 2007). Southern Africa is expected to experience increases in temperature and declining rainfall patterns as well as increased frequency of extreme climate events (such as droughts and floods) as a results of climate change (Nhemachena, 2008).

It was also suggested by World Bank (2010) that South Africa has been getting hotter over the past four decades with average minimum monthly temperature at 138 degrees Celsius and average maximum monthly temperature at 260 degrees Celsius. There has also been an increase in the number of warmer days and a decrease in the number of cooler days. Moreover, the country average rainfall, estimated at 450mm per year, is well below the average of 860mm (World Bank, 2010). In addition, surface and underground water resources are limited.

Agriculture is expected to be the most affected by these changes because it is highly dependent on climate variables such as temperature, humidity and precipitation (IPCC, 2011).

According to Kgakatsi (2006) climate change can be regarded as the silent enemy likely to affect already high risk and stressed agro ecosystems as the effects of climate change are not immediately visible. Limpopo province is particular vulnerable to climate variability and change as agricultural production depends on climatic conditions and largely on the quality of the rainy season. According to Letsatsi – Duba (2009) climate change in Limpopo province is taking place in the context of other developmental stresses, notably poverty, unemployment and food insecurity which it is feared that it will exceed the limits of adaptation in other parts of the province. It is thus important to develop and implement effective adaptation measures so that climate-related risks and opportunities might support development objectives within provincial policy decision making processes.

The rural community of Limpopo province places great emphasises on growing maize and vegetables. However, adverse climatic conditions will have a bearing on their agricultural production (Mpandeli et al., 2005). This is more likely to affect women more than men as they spend most of their income on food purchases (Makhura, 2001). It could also mean that they now have to spend more time on food gathering processes than before, as less food will be available to families.

The objective of this paper was first to understand the impacts of climate variability and change on agricultural production Limpopo province. Secondly was to assess the impacts of climate variability and change on agricultural production in Limpopo province and thirdly identify adaptation measures that reduce the impacts of climate variability and change on agricultural production in Limpopo province.

2. Data Collection

This paper used both quantitative and qualitative designs as questionnaire which included matters relating to climate change and agricultural production was used in the interviews and focus group discussions was conducted after face to face interviews with farmers. A temperature, rainfall and humidity parameters for the past 30 – 50 years for two selected districts was obtained from the South African Weather Services. Data on crops yield, tons, production and percent area planted for the past 30 – 50 years was obtained from the National Department of Agriculture. Permission was asked from the two district offices to conduct research in their different local municipalities. The following local municipalities were visited: *Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane and Molemole*. The survey targeted three hundred farmers in Sekhukhune and Capricorn Districts. The two districts namely Sekhukhune and Capricorn were asked to provide the list of farmers in their municipalities.

3. Method

Purposeful sampling technique was used to select three hundred farmers to be interviewed inorder to cover uniformity and homogenous characteristics of farmers. The mixed questionnaire included matters relating to climate change and agricultural production were used in the interviews. Before the interviews start a village meeting was conducted with all community representatives present: chiefs, indunas, local councillors and NGO's. The nature of the research and the contents of the questionnaire were explained to them. Focus group discussion was conducted after face to face interviews with farmers

3.1 Univariate Analysis Model

Univariate analysis is able to demonstrate the relationship between dependent and independent variables as stated in the general equation below:

$$W_i = _ + _X_i + _i \quad (1)$$

3.2 Multivariate Analysis Model

The application of multivariate analysis depends on many factors such as nature of variables used, research question, experimental design etc. The equation can be written as follows:

$$W_i = _ + _1INFC_i + _2ADCI + _3INFEX_i + _4SEXF_i \quad (2)$$

4. Results

Looking at the farming activities, most farmers fall in 50 – 65+ age group as indicated in Table 1 and this can be as the result of lack of interest in agricultural production from other age categories. This is because young people have identified other opportunities than farming activities in the province, e.g. tendering opportunities with various government departments in the province. It is found from literature that there is variation in age on

adoption decision. According to Bekele & Dekele (2003) age had no influence on a farmer’s decision to participate in climate change adaptation activities. However, according to Bayard et al. (2007) age is positively related to some climate change adaptation measures. Most farmers in Limpopo province assume that old age is associated with more experience and they expect older farmers to adapt to changes in climate while young farmers are expected to have longer planning horizon and thus to take long term adaptation measures.

Table 1. Age of farmers

Variable	Number of Farmers	Percentages
16 – 24	6	2
25 – 34	44	13
35 – 49	61	18
50 – 64	87	26
65+	102	41
Total	300	100

Education and employment are important factors influencing decision to adapt. Most of the farmers in the study have completed some primary education (28.3 percent) while only few farmers have university degree (6 percent) as seen in Table 2. The majority of farmers work fulltime on their farms (97.3 percent) as seen in Table 2. According to Anley et al. (2007) improving education and employment is key to stimulate local participation in various adaptation measures and natural resource management initiatives. 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 2. Education level of farmers

Variable	Number of Farmers	Percentages
No Formal Schooling	20	7
Some Primary Education	63	21
Primary Education Completed	85	28.3
Some Secondary Education	54	18
Secondary Education Completed	33	11
Post Secondary Education	19	6.3
Certificates	8	2.7
University Degree	18	6
Total	300	100

Perceptions on long-term temperature are divided into five categories as can be seen in Figure 1. The results indicate that 54.7 percent of farmers perceive that long-term temperatures are increasing. This is true as Jarraud (2011) emphasised that over the last ten years from 2001 to 2010, global temperatures have averaged 0.46°C above the 1961-1990 average, and are the highest ever recorded for a 10-year period since the beginning of instrumental climate records. Only few farmers believed temperature was decreasing, which is an indication that there is change in temperature. On the other hand, the overall perception on long term changes in precipitation is that Limpopo province as indicated in Figure 2 is getting drier and that there are pronounced decreased rainfall altered climatic changes and frequency of droughts (52.7 percent, 15 percent and 8 percent). This shortage of water will have a negative impact on agricultural production.

At least 74 percent of farmers received no support to adapt against changing weather patterns as indicated in Figure 3. Only 5.7 percent farmers received credit; 6.3 percent received insurance and 6.7 percent received subsidies. This is not good at all because lack of credit, insurance and subsidies limit the ability of farmers to get the necessary resources and technology they might need in order to adapt to climate change. According to Kandlinkar and Risbey (2000) since most farmers in Africa are operating under resource limitations: (a) lack of

credit, (b)subsidies and (c)insurance will accelerate farmers’ failure to meet transaction costs necessary to acquire adaptation measures as a result of unexpected weather patterns.

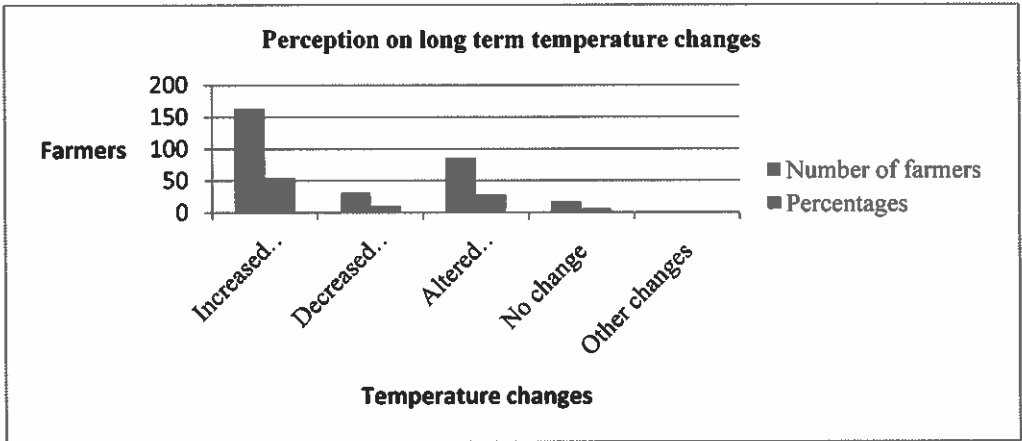


Figure 1. Perception on long term temperature changes

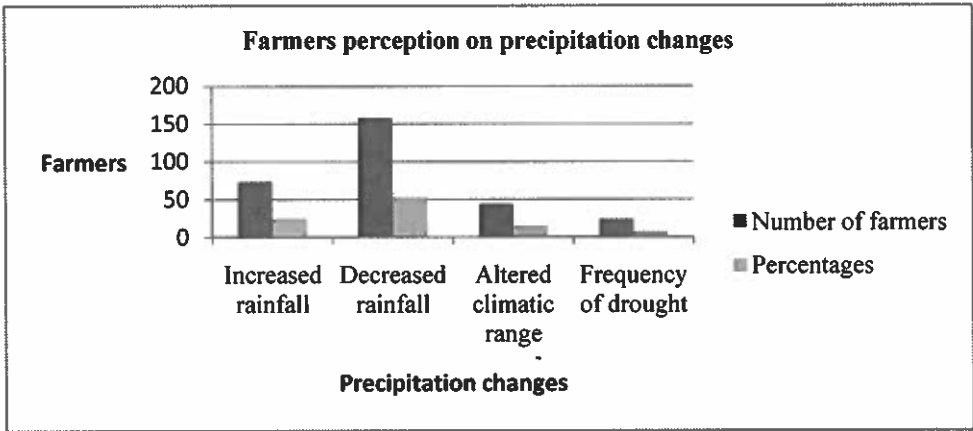


Figure 2. Farmers perception on precipitation changes

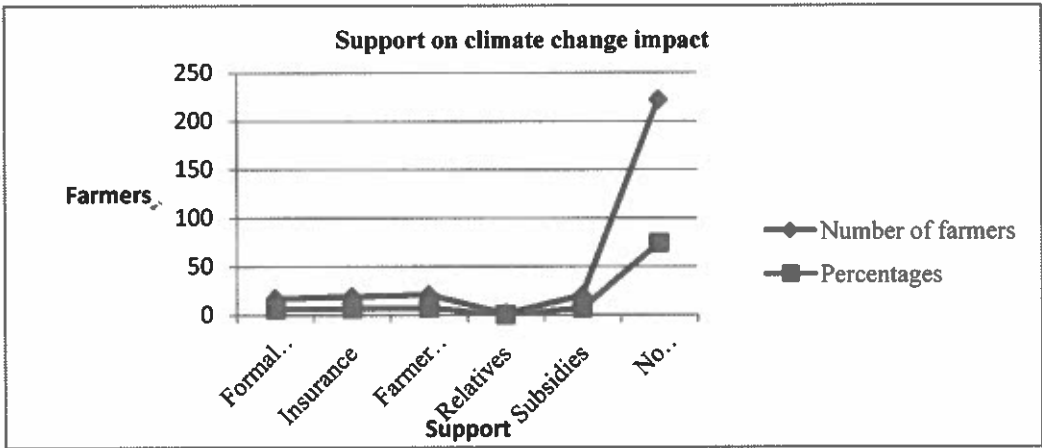


Figure 3. Support on climate change impact

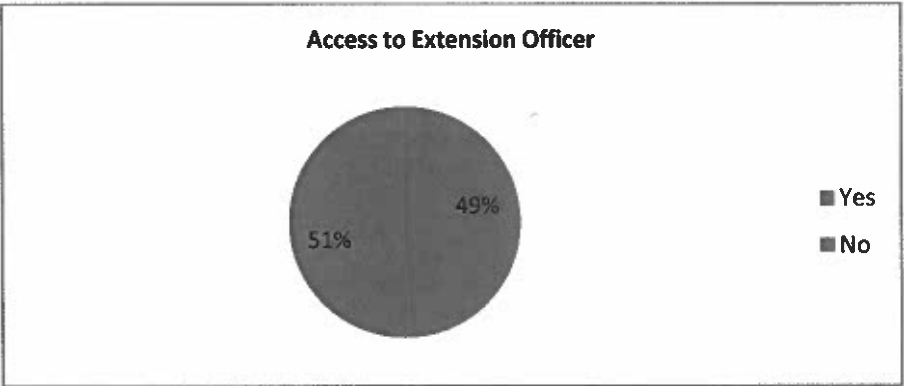


Figure 4. Access to Extension Officer

Extension a service was received by only 49 percent of farmers as indicated in Figure 4. This is good because extension services enhance the efficiency of making adaptation decisions. This was also recognised by Adesina and Forson (1995) that of many sources of information available to farmers, extension services is the most important for analysing the adaptation decisions. Adesina and Forson (1995) further hypothesized that access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills.

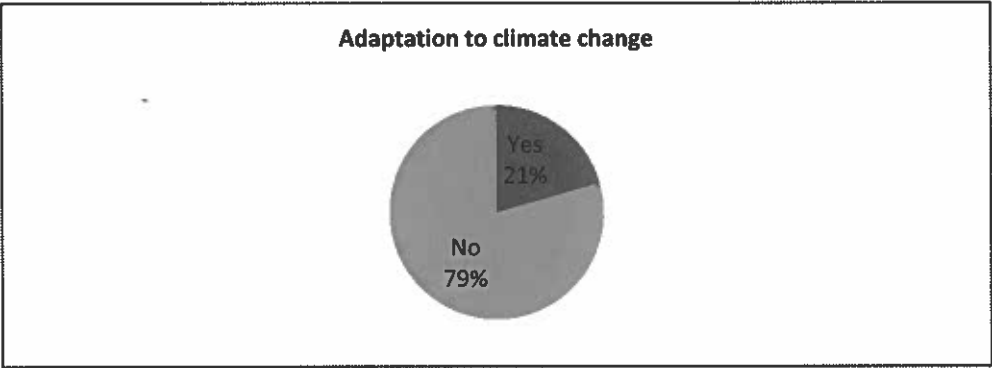


Figure 5. Adaptation to climate change

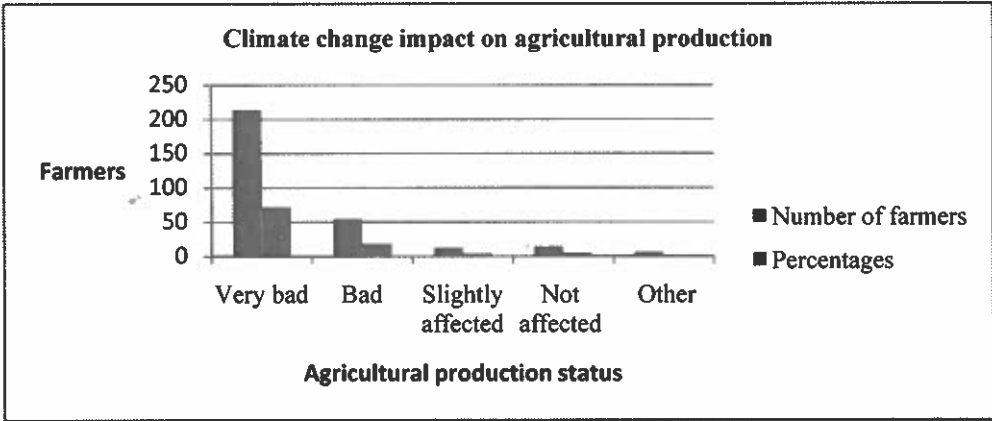


Figure 6. Climate change impact on agricultural production

Based on farmer’s response in this paper, it is not surprising to find 79 percent of farmers being unable to adapt as shown in Figure 5. According to Vogel and Reid (2005) the most important thing to adapt against changing

weather patterns is to strengthen social, economic and environmental resilience of the most vulnerable communities. The climate variability and change situation in Limpopo province has in fact affected farmers agricultural production as evident in Figure 6, whereby 71.3 percent of farmers agreed that climate change has in fact affected their agricultural crop production very bad. This is true as Mpandeli (2005) found that the impact of lower rainfall has negative effects on the agricultural sector and low rainfall will result in (a) decreases in agricultural activities, (b) loss of livestock, (c) shortage of drinking water, (d) low yields and shortage of seeds for subsequent cultivation.

5. Discussion

The sample consists of both male and female farmers, with 46 percent male and 54 percent female as seen in Table 3. Various studies have shown that gender is an important variable affecting adoption decisions at the farm level. According to Bayard et al. (2007) female farmers are more likely to adopt natural resource management and conservation practices. It was also emphasised by Burton et al. (1999) that female farmers are indeed important in the choice of agricultural practices to adopt, particularly in regard to conservation or sustainable technology. According to Nhemachena & Hassan (2007) the possible reason for female to adapt is that in most rural smallholder farming communities, men are more often based in towns, and much of the agricultural work is done by women. Therefore, women have more farming experience and information on various management practices and how to change them, based on available information (Anim, 1999).

Table 3. Summary characteristics of sample in 10 local municipalities

Variable	Total	Percentage
<i>Number of Farmers per District</i>		
Capricorn	167	56
Sekhukhune	133	44
<i>Number of Farmers per Local Municipality</i>		
Aganang	26	8.7
Blouberg	16	5
Polokwane	31	10
Lepelle Nkumpi	51	17
Molemole	43	14.3
Greater Tubatse	22	7
Makhuduthamanga	20	6.7
Fetakgomo	31	10.3
Ephraim Mogale	52	19
Elias Motsoaledi	8	2.3
<i>Sex of Farmers</i>		
Male	136	46
Female	164	54
Total	300	100

But according to Bekele & Drake (2003) gender has no significant factor in influencing farmers' decision to adopt climate change adaptation measures. They stressed that there is a significant difference in farmer's ability to adapt to climate change due to major differences between them in terms of access to assets, education, credit, technology and input supply.

Table 4 presents farmers perceptions on climate variability and change and 50 percent of farmers prefer crop diversification as one of their adaptation strategy. Crop diversification can also serve as insurance against rainfall variability as different crops are affected differently by climate events (Orindi & Eriksen, 2005; Adger et al., 2003). As an adaptation to late rain onset some farmers identified the following strategies to adapt as seen in Table 4: use different planting dates (15.7 percent); plant different crops (39 percent); plant different varieties (35 percent). It very clear from the above crop management strategies that majority of farmers did not recognise some of these strategies but there is a tendency that some farmers perceived those crop management strategies which is encouraging. The majority of farmers perceive that soil fertility management may help them against climate variability and change. As seen in Table 4, almost 53 percent of farmers think change use of fertilisers, chemicals and pesticides will improve their adaptation capacity against climate change. According to IPCC (2011) chemicals, fertilisers and pesticides can improve crop yields tremendously but can also be costly to the

environment. That is why some farmers in Limpopo province are applying organic fertilisers such as those resulting from composting. They believe that by emphasising on organic farming carbon is stored in soils and contribute significantly to the reduction of greenhouse gas emissions. This is true as carbon sequestration in soil has been recognised by Intergovernmental Panel on Climate Change and European Union as one of the possible measures to mitigate greenhouse gases.

Table 4. Descriptive analysis (Perceived farmers adaptation strategies in Limpopo province (% of respondents))

Variable	Number of Farmers	Percentage
Plant different varieties		
Yes	105	35
No	195	65
Plant different crops		
Yes	118	39
No	182	61
Crop diversification		
Yes	151	50
No	149	50
Use different planting dates		
Yes	47	15.7
No	253	84
Shorten growing period		
Yes	2	1
No	298	99
Move to different site		
Yes	7	2
No	293	98
Change land size		
Yes	5	2
No	295	98
Change crops to livestock		
Yes	2	1
No	298	99
Change from farming to non farming		
Yes	10	3
No	290	97
Increase irrigation system		
Yes	198	66
No	102	44
Change use of fertilisers, chemicals and pesticides		
Yes	158	53
No	142	47
Increase water conservation		
Yes	17	6
No	283	94
Soil conservation		
Yes	22	7
No	278	93
Use insurance		
Yes	39	13
No	261	87
Use subsidies		
Yes	43	14
No	257	86
Total	300	100

Water management strategies like increased irrigation system was the most perceived strategy of them all. This is not surprising given the socio- economic challenges in Sekhukhune and Capricorn districts. The majority of farmers believe irrigation systems could make them adapt to climate change variability and change. Sixty six percent of farmers prefer improved irrigation systems. The use of irrigation has the potential to improve agricultural productivity through supplementing rainwater during dry spells and lengthening the growing season (Baethgen et al., 2003; Orindi & Eriksen, 2005). It is important to note that irrigation water is also subject to impacts from climate change. Use of irrigation technologies need to be accompanied by other crop management practices such as use of crops that can use water more efficiently. Important management practices that can be used include: (a) efficient management of irrigation systems, (b) growing crops that require less water, and (c) optimizing of irrigation scheduling and other management techniques that help reduce wastage (Loë et al., 2001). Other perceived strategies were mentioned by few farmers to deal with climate variability and change like (1) Use insurance; (2) Use subsidies; (3) Change land size; (4) Change crops to livestock; (5) Shorten growing period were not popular among most of the farmers.

The results of univariate and multivariate analysis were presented in Tables 5 and 6. The results indicated that if the odds ratio is < 1 it means there is a less association among variables and if odds ratio is > 1 the association is great among variables. All variables are at 95% confidence interval. Variables that are associated with each other were: employment, sex of farmers, adaptation to climate change, access to information, information received through extension services, agricultural production, food scarcity, food security and unemployment.

Table 5. Univariate analysis of potential determinants of agricultural production

Variable	Total	Agric Production (%)	OR [95%CI]
Sex of farmers			
Male	136	6.6	1.00[0.373 – 2.403]
Female	164	6.3	1
Employment			
Working fulltime	292	6.5	0.72[0.285 – 1.141]
Working part-time	8	0	1
Information of climate change			
Yes	171	2.9	4.50[1.585 – 12.697]
No	129	11.9	1
Adaptation to climate change			
Yes	55	1.8	5.01[1.654 – 38.383]
No	245	8.5	1
Information received through extension Services			
Yes	146	4.1	2.45[1.585 – 12.697]
No	154	9.5	1

OR= Odds ratio; 95%CI = 95% confidence intervals.

According to Table 5 the odds of being affected by climate change are 1.00 percent higher for male farmers than female farmers. This situation is not surprising because it should be acknowledged that women play a vital role in supporting households and communities to adapt to climate change through experience gained in agricultural production. In Africa, for instance women are the primary producers of staple food and they contribute much of labor that will go into coping with climate risks through soil and water conservation (UNDP, 2009). This situation is not different from Limpopo province, where most information was given by female farmers. According to UNDP (2009) across developing countries women's leadership in natural resource management is well recognized. Women for centuries have passed on their skills in water management, forest management and the management of biodiversity, among others.

The odds of being affected by climate change are 0.72 times less for fulltime farmers than those part-time farmers as indicated in Table 5. This is true because being fulltime farmer increases the ability to take adaptation options. The response of farmers in Limpopo province is in line with the study conducted by Nhemachena & Hassan (2007) that fulltime farmers will not be affected much by climate change because they are more likely to have more information and knowledge on changes in climatic conditions than part-time farmers. Most of these farmers can also be targeted in promoting adaptation management by government to other farmers who do not have relevant experience and are not yet adapting to climate variability and change.

As indicated in Table 5 the odds of being affected by climate change is 4.50 percent times higher for farmers with information on climate change than those without information on climate change. This situation shows a bleak picture on access to climate information in Limpopo province. Limpopo province farmers should understand that information regarding climate change forecasting, adaptation options and agricultural activities are not easily available on radio and this increases high risks associated with climate variability and change. According to Baethgen et al. (2003) availability of climate and agricultural information helps farmers to make comparative decisions in agricultural production and this allows them to better choose strategies that encourage climate variability, change and adaptation.

Another disturbing response is that of access to extension services by farmers. According to Table 5 the odds of being affected by climate change is 2.46 times higher for farmers that received information through extension services than those who did not receive information through extension services. This situation does not surprise me because some farmers especially resource poor farmers, were complaining that some extension officers do not have relevant qualifications to do the job. Again some extension officers were also complaining that government is not organising relevant training courses that deal with climate variability and change and agricultural production. This is a clear indication that extension officers need to be re-trained in order to provide valuable information to the farmers so that farmers can value them. As Mmbengwa (2009) emphasised that extension services have an important role to play in assisting farmers to acquire new technology, skills, innovation and production advice. So Limpopo farmers and government should priorities extension service because it will significantly increase farmer awareness of changing climatic conditions as well as adaptation measures in agricultural production.

According to Table 5 the odds of being affected by climate change are 5.01 times higher for farmers that can adapt to climate change than those who cannot adapt to climate change. This situation shows that even if some farmers are trying to adapt, the impact of climate change on agricultural production is a reality. Majority of farmers in those districts have agreed that they don't have capacity to adapt but the results also shows that even those who adapt are at risk against changing weather patterns. According to Maddison (2007) situation like this can be addressed by governments like Department of agriculture and forestry, Agricultural research council and South African weather services to raise awareness of the changes in climatic conditions through appropriate communication pathways that are available to farmers such as extension services, farmer groups, input and output dealers, radio and televisions among others. This needs to be accompanied by the various crop and livestock management practices that farmers could take up in response to forecasted changes in climatic conditions such as varying planting dates, using irrigation, or growing crop varieties suitable to the predicted climatic conditions.

Table 6 presents multivariate logistic regression models of agricultural production, unemployment and food scarcity as key outcome variables and information of climate change, adaptation to climate change, information received through extension and services sex of farmers were some of the covariates used. Model I shows that the odds of being affected by climate change are 0.56 less for farmers that receive information of climate change than farmers that do not receive information of climate change. The model also shows that the odds of being affected by climate change are 1.05 higher for farmers who can adapt than farmers that cannot adapt to climate change. It further concludes that the odds of being affected by climate change are 0.54 less for farmers who receive climate change information through extension services than those that do not receive information through extension services. This result showed that through combination of adaptation strategies farmers can be able to adapt against climate variability and change and thus improve agricultural production. Information of climate change is significant in this model at 0.015.

Table 6. Multivariate logistic regression model on Agricultural Production; Unemployment and Food scarcity

Variable	OR (*p – value)
Model I (Agricultural Production)	
Information of climate change	
Yes	0.56(0.015)
No	1
Adaptation to climate change	
Yes	1.05(0.239)
No	1
Information received through extension services	
Yes	0.54(0.413)
No	1
Model II (Unemployment)	
Sex of farmers	
Male	0.39 (0.017)
Female	1
Information received through extension Services	
Yes	0.28(0.134)
No	1
Model III (Food Scarcity)	
Information of climate change	
Yes	0.35(0.016)
No	1
Adaptation to climate change	
Yes	0.48(0.433)
No	1

OR = Odds ratio; * X²

Model II focused on sex of farmers and information received through extension services. The model shows that the odds of being affected by climate change are 0.39 less for male farmers than female farmers. It also shows that the odds of being affected by climate change are 0.28 less for farmers who receive climate change information through extension services than those that do not receive information through extension services. These results showed that by being fulltime farmer with extension services support, farmers can adapt to climate variability and change. This will in turn eradicate unemployment levels. The model concludes by emphasising that sex of farmers is significant at 0.017.

Model III showed that the odds of being affected by climate change is 0.35 less for famers with information of climate change than farmers that do not have information of climate change. This showed that farmers with climate change information will not experience food scarcity. It further showed that the odds of being affected by climate change are 0.48 less for farmers that can adapt to climate change than those that cannot adapt to climate change. It showed that farmers who adapt to climate change cannot experience food scarcity and further showed the importance of using combination of adaptation measures to adapt against climate variability and

change. Information of climate change is significant in this model at 0.016. It can be concluded that information of climate change plays a very important role in agricultural production and food scarcity as seen in Model I and Model III. These models are consistent with Baethgen et al. (2003) who said the availability of climate and agricultural information helps farmers to make comparative decisions in agricultural production and this allows them to better choose strategies that encourage climate variability, change and adaptation.

6. Summary and Conclusion

According to IPCC (2011) the scientific community widely agreed that climate variability and change is already a reality. Over the past century, surface temperatures have risen, and associated impacts on physical and biological systems are increasingly being observed. Climate variability and change will bring about gradual shifts such as sea level rise, movement of climatic zones due to increased temperatures, and changes in precipitation patterns. Climate variability and change is also likely to increase the frequency and magnitude of extreme weather events such as droughts, floods and storms and Limpopo Province has already experienced some these weather events especially floods and droughts, example, floods that destroyed crops, infrastructure, affected the harvesting period in 2000 and January 2012. While there is uncertainty in the projections with regard to the exact magnitude, rate and regional patterns of climate variability and change, its consequences will change the fates of generations to come.

Therefore there is a need for urgent adaptation strategies in the agricultural sector is required to the changes in climate especially in Africa where millions of people depend on it for survival. According to UNFCCC (2008) Africa will be hit hardest by climate change as larger areas could be stricken by yield decreases of over 50 percent by the year 2020 as results of increasingly hotter and drier climate. This will threaten food security and people livelihoods in most parts of Africa. It is against this background that means have to be found to adapt to climate variability and change and therefore essential for development partners to deliver on their commitments to support African countries to adapt to the unavoidable impact of climate change which includes scaling up efforts in order to (a) improve and increase access to climate data; (b) investment and transfer of technologies for adaptation in key sectors; (c) developing and implementing best practice guidelines for screening and assessing climate change risk in their development projects and programs in climate sensitive sectors; (d) mainstreaming climate factors into development planning and implementation; (e) providing significant additional investment in disaster prevention. The summary and conclusions are presented under the following headings: (a) Information of climate change, (b) Adaptation to climate change, (c) Information received through extension services, (d) Drought, (e) Indigenous coping strategies and (f) Crop diversification.

(a) Information of climate change

Farmers need adequate knowledge about the importance of climate change in order for these farmers to be able to adapt effectively. So, transfer of climate knowledge to support vulnerability and adaptation measures are advocated in this regard. To accomplish these farmers should use different information sources like the media both printing and the electronic, research institutions such as the Agricultural Research Council, agricultural extension services and civil societies like NGOs for the dissemination of the climate change, climate advisory information across various farmers in the province.

(b) Adaptation to climate change

The extreme weather patterns caused by climate variability and change in Limpopo province have impacted the farming communities severely for the past several years. The majority of these farmers have limited adaptive capacity, finance and technology to respond towards climate change challenges. These farming communities must use identified adaptation measures in this study and use the resources available to them to tackle climate variability and change.

(c) Information received through extension services

The role of agricultural extension officers should be further explained to the farming communities in Limpopo province. This must include Agricultural extension officers role in encouraging farmers to adopt new technologies, improved methods of farming, using a variety of methods to reach farmers i.e. organizing study groups for farmers, farmer days, demonstrations, lectures and literature, as well as informing the media about farmers challenges.

(d) Drought

Drought is a recurring problem in Limpopo province. According to Mpandeli (2005) in times of drought, different coping strategies should be gathered, understood and shared amongst a range of end users e.g. either by the National agro meteorological committee, research institutions such as Agricultural Research Council and the

South African Weather Service. Limpopo farmers should also be encouraged to use drought-resistant cultivars during drought periods.

(e) Indigenous coping strategies

Indigenous coping strategies should play an integral role in building climate resilience. Indigenous coping strategies must not only be sought and recognized, but also integrated with conventional science if farmers are planning to tackle climate change challenges in the agricultural sector

(f) Crop diversification

Farmers should be encouraged and enabled to use crop diversification as adaptation coping strategy. This is a common practice to find many crop species on the same piece of land to guard against crop failure in times of adverse climatic conditions.

The results of this paper are potentially valuable to the agricultural sector considering the international and local debate and interest in order to counter act the impact of both the climate variability and change.

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APPENDIX G: PAPER ACCEPTED

African Journal of Agricultural Research

Full Length Research Paper

Impact of drought on food scarcity in Limpopo province, South Africa

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Drought in Limpopo province is having serious ecological and economic consequences and will pose an increasing challenge to communities as the global climate is changing. A representative sample of 300 farmers aged 16 to 65+ years was used. The study involved Sekhukhune and Capricorn districts. The following 11 local municipalities were visited: Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane, and Molemole. The results showed that current Limpopo province weather is dominated by drought and as results of the severe drought the province experienced reduced grazing and water for livestock and irrigation which negatively impacted the agricultural sector and hence resulting in food scarcity. The results also indicated that in some parts of the Limpopo province, farmers are already forced to sell their livestock because of drought conditions, and that there was a shortage of rainfall in the following years: 1982, 1983, 1984, 1986, 1990, 1991, 1992, 1993, 1994, 2002, 2003, 2005, 2008 and 2009, respectively. The results showed enhanced probabilities of 50% for above normal maximum temperatures in the entire Limpopo province. This is again raising very serious temperature trends in Limpopo province which will increase poor rainfall patterns and accelerate frequency of droughts. This will in turn place a serious challenge for agriculture, not only in the province but South Africa as a whole because a sharp decline in agricultural production would not only have implications for a province or country but also for the region as a whole.

Key words: Drought, climate variability, climate change, agricultural production, food scarcity, Limpopo province, South Africa.

INTRODUCTION

Limpopo Province is one of South Africa's richest agricultural areas. It is a major producer of vegetables. The subtropical climate enjoyed by much of the province gives rise to the cultivation of tea, coffee and fruits, especially tropical fruits. Forestry makes a major contribution to the economy, as do tobacco, sunflower, wheat, cotton, maize, and groundnuts. Livestock farming includes cattle ranching and game. The abundance of orchards with various sub-tropical fruits and nuts form the basis of a thriving agro-industrial sector (StatsSA, 2006).

Drought is emerging as one of the main challenges Limpopo province farmers will have to face for many years to

come (Makhura et al., 2004). It could become a major threat to food security, as it has a strong impact on food production, access and distribution. Furthermore, given an estimate of 3 million farmers in South Africa who produce food primarily to meet their family needs, rural poverty in Limpopo province could be worsening with drought (StatsSA, 2007). Indeed, due to their low income, lower technological and capital stocks, households are predicted to have limited options to adapt to changing weather patterns like drought (Mendelsohn et al., 2000).

Drought is a serious problem in the province considering the fact that the province is in a semi arid area with low, unreliable rainfall (LDA, 2010). The impact of lower rainfall has negative effects on the agricultural sector, low rainfall resulting in decreases in agricultural activities, loss of livestock, shortage of drinking water, low yields and shortage of seeds for subsequent cultivation. Limpopo province is a

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LIMPOPO PROVINCIAL MAP

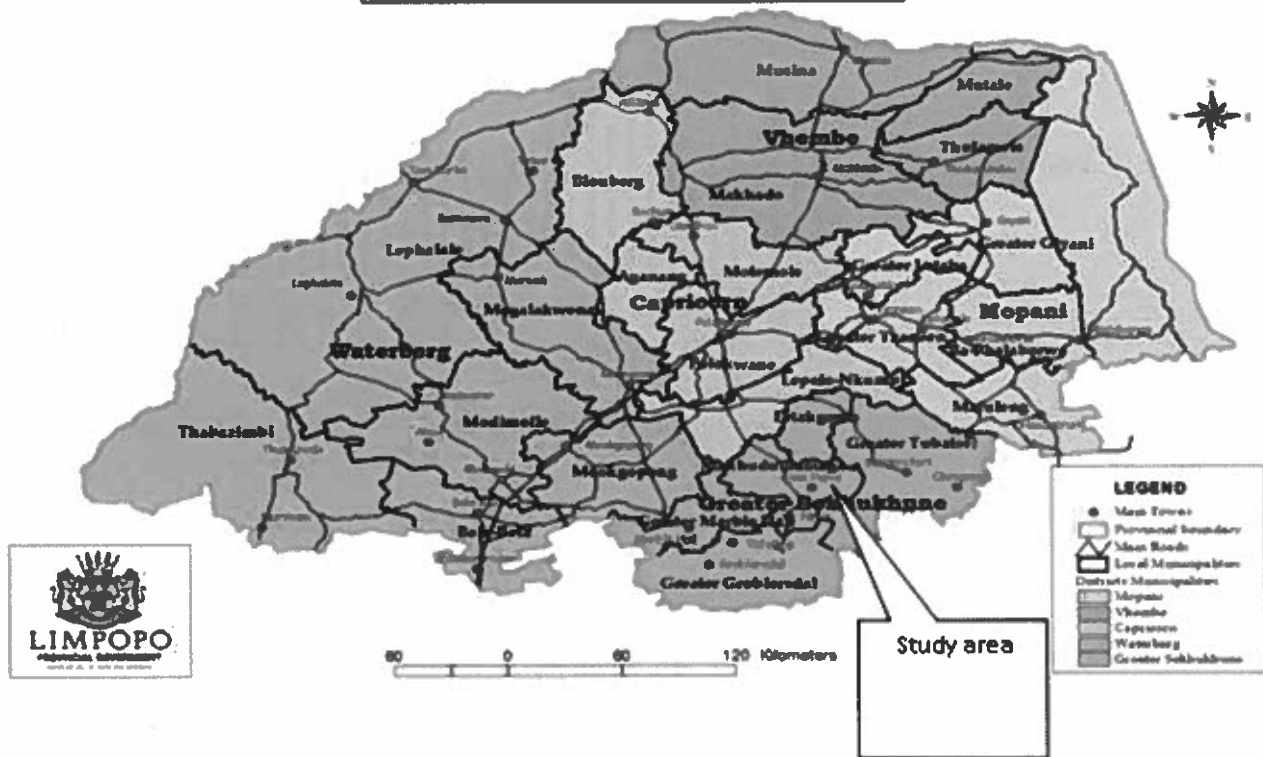


Figure 1. Geographic location of the greater Sekhukhune and Capricorn districts in Limpopo province. Source: StatsSA (2006).

drought prone province which faces challenges of drought from time to time. As a result of the severe drought, the province experienced reduced grazing and water for livestock and irrigation which negatively impacted the agricultural sector. Limpopo province was worst affected by drought in the past eight years where dams were only 50% full, compared with 84% in late nineties. The agricultural sector is also seen as an important source of livelihood for the Limpopo province especially those in rural areas, but with extreme weather like drought, it is going to be very difficult for people to cope. It is quite disturbing that in some parts of the province, farmers are already forced to sell their livestock because of drought conditions. This will in turn place a serious challenge for agriculture and result insufficient/shortage amount of food (food scarcity) not only in the province but South Africa as a whole. According to Makhura (2001), a sharp decline in agricultural production would not only have implications for a province or country but also for the region as a whole.

On the geographical locality of the study site, Limpopo province is situated in the northern part of South Africa. It is the gateway to the rest of Africa, with its shared borders making it favourably situated for economic cooperation with other parts of Southern Africa (StatsSA, 2011). Two districts

were selected as the study areas, namely Greater Sekhukhune and Capricorn (Figure 1). This was based on different agricultural setups and the different climatic conditions.

The paper was guided by the following hypothesis: (a) In Limpopo province, areas that are hot and dry, increases in warming and declining precipitation are expected to have negative impacts on agricultural crop production, (b) in Limpopo province, there are districts that are experiencing dry and average wet conditions, increases in seasonal rainfall are expected to increase agricultural crop production, (c) improved access of Limpopo farmers to resources such as credit, extension, information etc, enhances farm level use of adaptation measures against changing weather patterns like drought. Considering the negative and unwanted impacts of drought and the geographic situation vulnerability of Limpopo province farmers especially its rural communities, there is a need to design purposeful, comprehensive/systemic mechanisms to cope with drought impacts. The first step in such a process is to obtain appropriate, up to date, relevant, exact knowledge and perception of the people involved in drought phenomena; and understanding its contexts, causes, interactions, and impacts. And the next step then

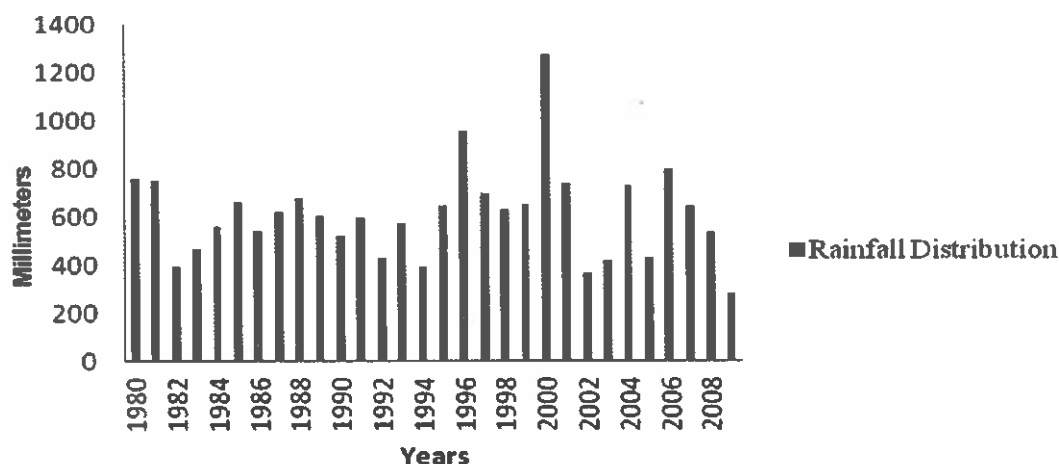


Figure 2. Rainfall distribution in Limpopo province (1980 to 2009). Source: SAWS (2012).

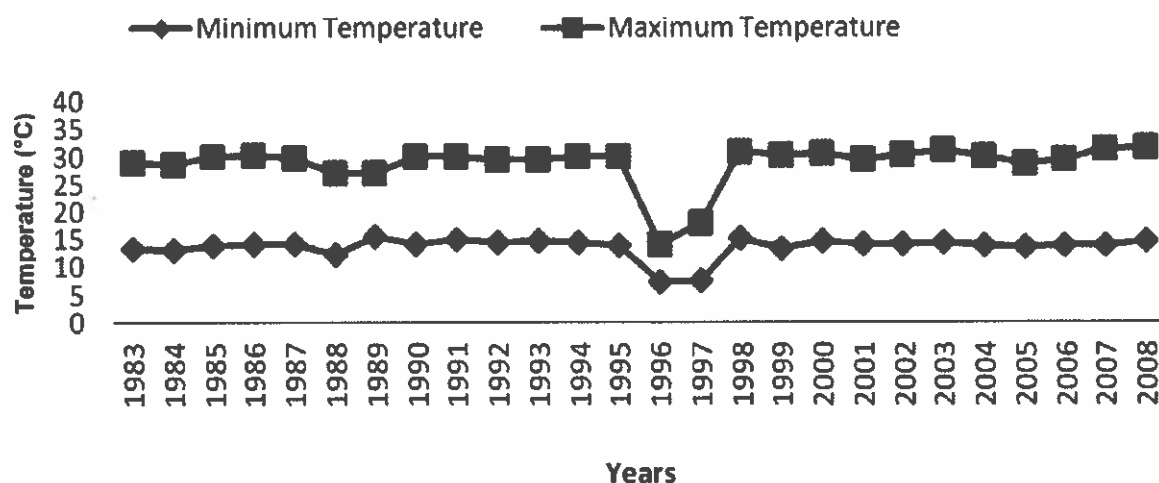


Figure 3. Capricorn district monthly average temperature: 1983 to 2008. Source: SAWS (2012).

would be identification of affective policies, approaches, and mechanisms for decision making and plans to cope with this phenomenon and reduce its impacts.

MATERIALS AND METHODS

This paper contains elements of both quantitative and qualitative research designs. According to Creswell (1994), mixed methods are used in order to explore a topic in breadth and depth, hence questionnaire which included matters relating to climate change and agricultural production was used in the interviews, and focus group discussions was conducted after face to face interviews with farmers.

Permission was asked from the two district offices to conduct research in their different local municipalities. The following local municipalities were visited: Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane and Molemole. The survey targeted three hundred farmers in Sekhukhune and Capricorn Districts. The two districts namely

Sekhukhune and Capricorn were asked to provide the list of farmers in their municipalities.

Limpopo province is one of South Africa's poorest and it is against this background that more research is needed to develop its agricultural sector since majority of the communities depend on it. The selection of two districts were based on different agricultural setups and different climatic conditions. The purposeful sampling method used covered most of the productive farms in the two selected districts in the province and also covered the uniform or homogeneous characteristics of farmers. The sample frame was designed to meet the objectives of the study, and it had to adhere to the statistical specifications for accuracy and representativity.

Rainfall distribution for the past 29 years was obtained from the South African Weather Services as seen in Figure 2. Average monthly Capricorn temperatures for the past 25 years was obtained from the South African Weather Services as seen in Figure 3. Average monthly Sekhukhune temperature for the past 25 years was obtained from the South African Weather Services as seen in Figure 4. Current rainfall outlook in Limpopo province was also obtained from South Africa Weather Service as indicated in Figure 5. Current temperature outlook in

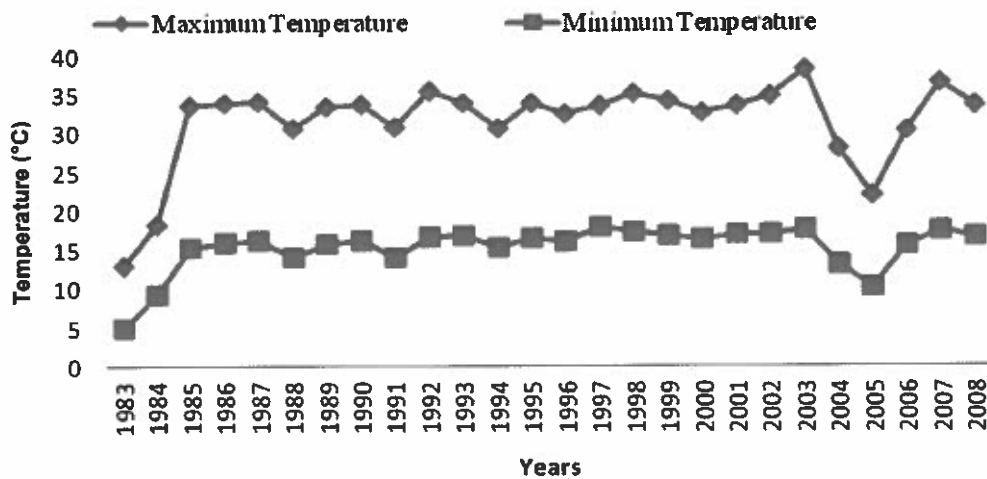
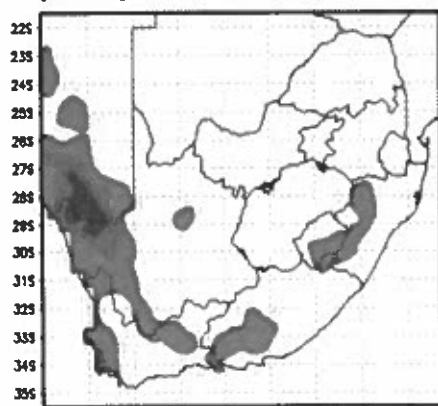


Figure 4. Sekhukhune district monthly average temperature: 1983 to 2008. Source: SAWS (South Africa Weather Service) (2012).

May to July: above normal rainfall



May to July: Below normal rainfall

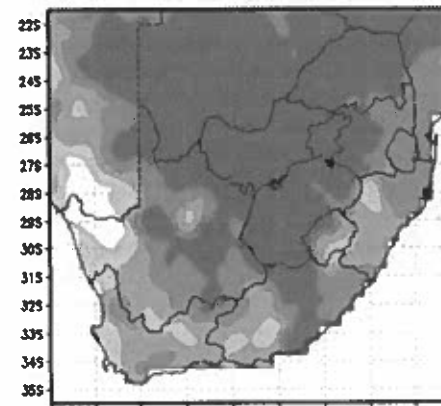
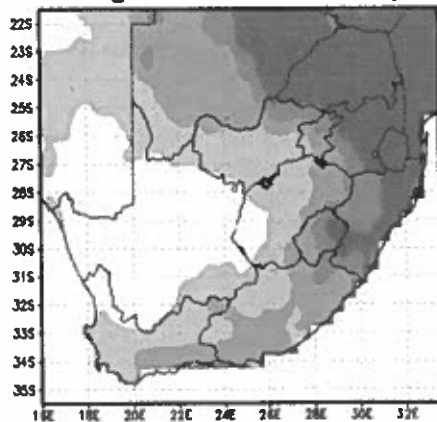


Figure 5. Rainfall outlook in Limpopo province: May to July, 2012. Source: SAWS (South Africa Weather Service) (2012).

June to August: above normal temperature



June to August: below normal temperature

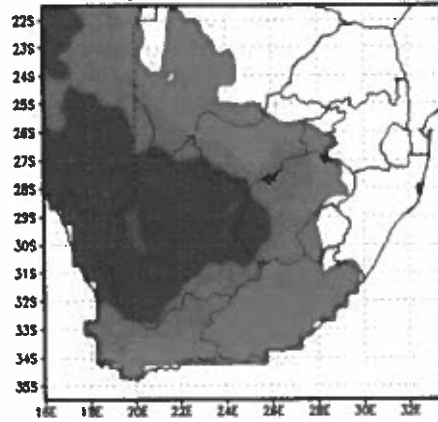


Figure 6. Temperature outlook in Limpopo province: June to August, 2012. Source: SAWS (South Africa Weather Service) (2012).

Limpopo province was also obtained from South Africa Weather Service as indicated in Figure 6. Univariate analysis was conducted to demonstrate the relationship between selected variables and food scarcity as stated in the general equation below:

$$W_i = \beta_0 + \beta_1 X_i + \epsilon_i \quad (1)$$

where, W_i is the dependent variable value for person i , X_i is the independent variable value for person i , β_0 and β_1 are parameter values, ϵ_i is the random error term. The parameter β_0 is called the intercept or the value of W when $X = 0$, the parameter β_1 is called the slope or the change in W when X increases by one.

RESULTS AND DISCUSSION

Rainfall distribution in Limpopo province (1980 to 2009)

As indicated in Figure 2, there is variation in rainfall distribution in Limpopo province overtime. According to LDA (2010), Limpopo province average annual rainfall is 600 mm and the threshold for rainfall agriculture is averaged at 250 mm annually. It is evident from Figure 2 that there was a shortage of rainfall in the following years: 1982, 1983, 1984, 1986, 1990, 1991, 1992, 1993, 1994, 2002, 2003, 2005, 2008 and 2009, respectively. According to Letsatsi-Duba (2009), the occurrence of drought in 2009 was the worst ever in Limpopo province.

This is also evident in Figure 2 which shows rainfall averaged to 282.1 mm annually in 2009, nearly dropping below threshold for rainfall agriculture. There were also good rainfall years in Limpopo province as shown in Figure 2, especially 1980, 1981, 2000 and 2001, respectively. In general, it can be concluded that rainfall distribution has indeed changed in the past 29 years in Limpopo province, and information on rainfall amount and variability is important for improved decisions making with regards to planting time, crops choice and crop variety etc.

As a result of the rainfall fluctuations over the past 29 years, it is important for farmers in the province to adopt multi cropping system in order to counteract the problem of drought across the districts.

Capricorn district monthly average temperature (1983 to 2008)

Capricorn district average temperatures trends shows high levels which are above South Africa average temperatures. Only few years namely 1988, 1996 and 1997 shows average temperatures that are below South Africa average temperatures as indicated in Figure 3.

This situation is also supported by Kruger and Shongwe (2004) who found that there was a significant increase in temperature between 1960 to 2003 for Polokwane, Bela Bela and Musina stations in the Limpopo province. This condition has led to occurrence of droughts around Capricorn district and put most communities vulnerable to food scarcity.

Sekhukhune district monthly average temperature (1983 to 2008)

According to Climate Info (2012), average minimum monthly temperature in South Africa is at 14°C and average maximum monthly temperature is 26°C. As indicated in Figure 4, Sekhukhune district temperature has been changing overtime and showed high temperature levels which are above South Africa average. These results are consistent with Hughes and Balling (1996) who reported that there is an increase in average temperatures per decade over the period 1960 to 1990, and these trends were significant for both non urban and urban stations. Figure 4 shows that only average temperatures in 1982, 1983, 2004 and 2005 were below the South Africa average temperature. This result also explains why Sekhukhune district is frequented by droughts and poor rainfall.

Rainfall outlook in Limpopo province (May to July, 2012)

As indicated in Figure 5, the rainfall outlook for Sekhukhune and Capricorn districts looks very bad. The results indicated that the probability of both districts in receiving below normal rainfall is 50% for May to July, 2012. It is evident from Figure 5 that there is no/little probability for both districts to receive above normal rainfall. This will create lot of problems for farmers and it will require the use of adaptation measures like using of drip irrigation which saves water irrigating during cool conditions to avoid evapotranspiration and to adhere to the water restrictions issued all the time.

Temperature outlook in Limpopo province (June to August, 2012)

The results in Figure 6 shows that average temperatures in Sekhukhune and Capricorn districts for June to August, 2012 is high. The results showed enhanced probabilities of 50% for above normal maximum temperatures in the entire Limpopo province. This is again raising a very serious temperature trends in Limpopo province, which will increase poor rainfall patterns and accelerate frequency of droughts. Perceptions on long-term temperature are divided into five as can be seen in Figure 7. The results indicate that 54.7% of farmers perceive that long-term temperatures are increasing. This is true as Jarraud (2011) emphasised that over the last ten years, from 2001 to 2010, global temperatures have averaged 0.46°C above the 1961 to 1990 average, and are the highest ever recorded for a 10-year period since the beginning of instrumental climate records. Only few farmers believed temperature was decreasing, which is an indication that there is change in temperature.

On the other hand, the overall perception on long term changes in precipitation is that Limpopo province as indicated in Figure 8 is getting drier and that there are

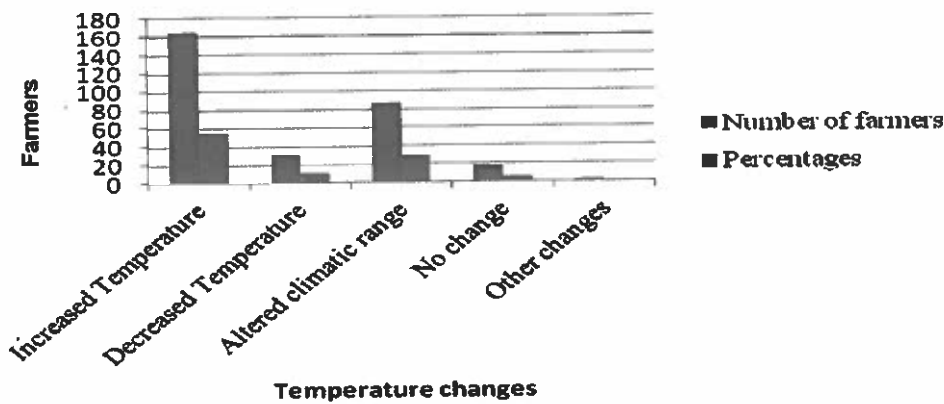


Figure 7. Perception on long term temperature changes.

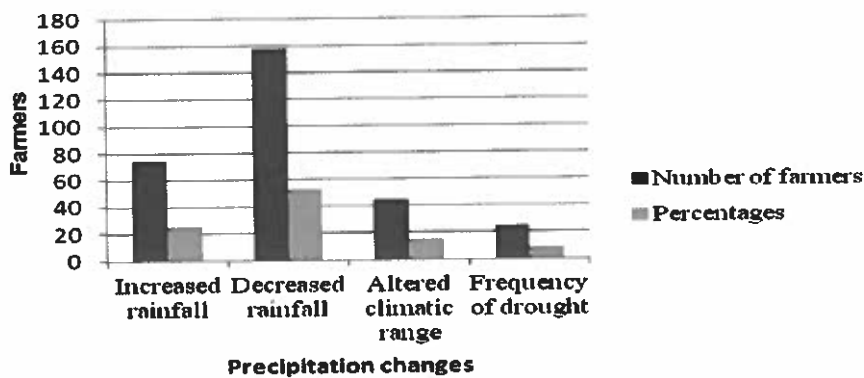


Figure 8. Farmers perception on precipitation changes.

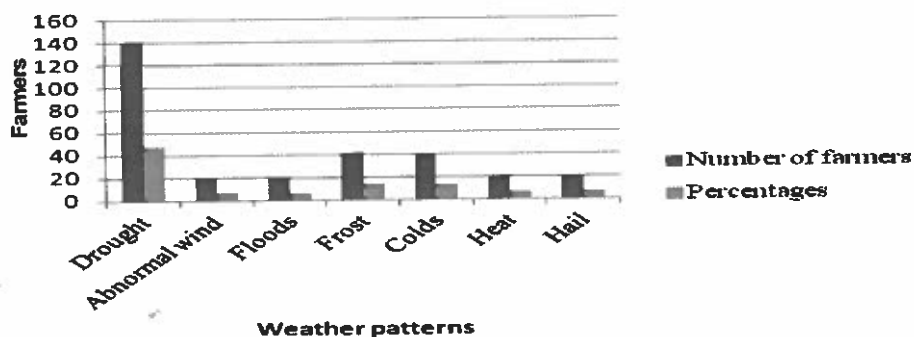


Figure 9. Current experience on weather patterns.

pronounced decreased rainfall altered climatic changes and frequency of droughts (52.7, 15 and 8%). This shortage of water will have a negative impact on agricultural production and thus resulting in food scarcity. It also evident from Figure 9, that current Limpopo province weather is dominated by drought as observed by 47% of farmers. This observation is in line with Letsatsi-Duba (2009) statement when she said

Limpopo province is a drought prone province which faces challenges of drought from time to time. As a result of the severe drought, the province experienced reduced grazing and water for livestock and irrigation which negatively impacted the agricultural sector.

As indicated in Table 1, the odds of farmers to face food scarcity are 1.00 times higher for male farmers than female

Table 1. Univariate analysis of potential determinants of food scarcity.

Variable	Total	Food scarcity (%)	OR [95%CI]
Sex of farmers			
Male	136	18.4	1.00[0.373–2.403]
Female	164	17	1
Information of climate change			
Yes	171	13.5	2.01[1.103–3.667]
No	129	23.8	1
Adaptation to climate change			
Yes	55	10.9	1.78[1.013– 4.464]
No	245	17.9	1
Information received through extension Services			
Yes	146	17.8	0.95[0.517–1.730]
No	154	17	1

OR = Odds ratio; 95%CI = 95% confidence intervals.

farmers. This is true as IPCC (2011) emphasised that women's knowledge of seed varieties, cultivation, storage, and use is a valuable form of human capital that makes them food secure.

According to FAO (2011), women also play an important role in postharvest activities, and as grains or other crops come in from the fields, women decides what will be stored , processed and saved for next year crops. These activities make women farmers more food secure than men farmers, especially during drought periods.

According to Table 1, the odds of farmers to face food scarcity is 2.01 higher for those that have access to climate change information than those who did not have access to information. Again, the results raised the issue of type of information farmers are receiving and the source they use in getting accurate information regarding drought.

The following sources are more popular among farmers in the Limpopo province: (a) radios, (b) television, (c) newspapers and (d) magazines.

As indicated in Table 1, the odds of farmers to face food scarcity are 1.78 times higher for farmers who adapt to climate variability and change than those who cannot adapt to climate variability and change. In view of this, it can be deduced that farmers do not have enough adaptation strategies hence they are still vulnerable to food scarcity. The odds of farmers to face food scarcity are 0.95 times less for farmers who receive information through extension services than those who do not receive information through extension services. This reflects the importance of extension services to avoid food scarcity.

Through extension services farmers can receives skills, knowledge to produce food even in times of drought. It was also supported by Mmbengwa (2009) who said farmers with access to extension services have better chance of engaging more profitably in agriculture than those that have no access.

Conclusion

Drought is a recurring problem in Limpopo province. According to Mpandeli (2005), in times of drought, different coping strategies should be gathered, understood and shared amongst a range of end users for example, either by the National agro meteorological committee, research institutions such as Agricultural Research Council and the South African Weather Service.

Limpopo province farmers should also be encouraged to use drought-resistant cultivars during drought periods to avoid food scarcity.

Rainfall distribution and temperature trends are likely to increase the frequency and magnitude of extreme weather events such as droughts in Limpopo province which has already experienced some these weather events especially floods and droughts, example, floods that destroyed crops, infrastructure, affected the harvesting period in 2000 and January, 2012 .

While there is uncertainty in the projections with regard to the exact magnitude, rate and regional patterns of drought, its consequences will change the fates of generations to come.

According to UNFCCC (2008), Africa will be hit hardest by climate changes, as larger areas could be stricken by yield decreases of over 50% by the year 2020 as results of increasingly hotter and drier climate. This will threaten food security and people livelihoods in most parts of Africa and thus resulting in food scarcity.

This study examined the trends of climate change factors such as temperature, rainfall overtime which may results in food scarcity. The results from the present study could be used as a baseline in understanding the consequences of drought on food scarcity.

As such, the analysis utilized the Statistical Package of

Social Science Software to determine variables associated with food scarcity.

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APPENDIX H: PAPER UNDER REVIEW

African Journal of Agricultural Research

APPENDIX I: PAPER ACCEPTED

Journal of Human Ecology

APPENDIX J: PAPER ACCEPTED

Journal of Agricultural Science

Climate Change Adaptation Strategies used by Limpopo Province Farmers in South Africa

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Abstract

The aim of the paper was to identify the adaptation strategies used by Limpopo province farmers against climate variability and change. A representative sample of 300 farmers aged 16-65+ years (46 percent males and 54 percent females) participated in the study. The study involved Sekhukhune and Capricorn districts, with 56 percent farmers in Capricorn and 44 percent in Sekhukhune district. The following 11 local municipalities were visited: Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane, and Molemole. Focus group discussions, questionnaire and observations were used to identify climate variability and change adaptation strategies in Limpopo province. The paper presented adaptation strategies of selected Limpopo province farmers. Some of their adaptation strategies included: (a) Use of DACOM system for monitoring, (b) Use of Indigenous Knowledge practices (c) Use of wind directions and clouds to determine rainfall expectation, (d) Use of nets to monitor temperature level etc. Other important adaptation strategies being used by farmers were also discussed in this paper including different adaptation measures against colds, heat, frost, abnormal wind, hail, lack of extension support, nematodes, insecticides, worms, temperature and rainfall. The adaptation strategies identified in this paper are potentially valuable to the agricultural sector considering the threats that climate change poses across climate sensitive sectors

Keywords: climate variability, climate change, adaptation strategies, Limpopo, South Africa

1. Introduction

According to IPCC (2007) Africa will be hit hardest by climate change as larger areas could be stricken by yield decreases of over 50 percent by the year 2020 as results of increasingly hotter and drier climate. This will threaten food security and people livelihoods in most parts of Africa. It is against this background that means have to be found to adapt to climate change and therefore essential for development partners to deliver on their commitments to support African countries to adapt to the unavoidable impact of climate change which includes scaling up efforts in order to (a) improve and increase access to climate data; (b) investment and transfer of technologies for adaptation in key sectors; (c) developing and implementing best practice guidelines for screening and assessing climate change risk in their development projects and programs in climate sensitive sectors; (d) mainstreaming climate factors into development planning and implementation; (e) providing significant additional investment in disaster prevention.

Limpopo province is one of the poorest provinces in South Africa. Climate change threatens the livelihood of the people. For instance as a result of drought many families lost their livestock and shortage of water was identified as the cause of the increased mortality rate of livestock (Letsatsi-Duba, 2009). At provincial and district levels there is awareness of the need to address climate impacts and adaptation and some assessments have highlighted the need for the development of adaptive strategies. At district level (Capricorn and Sekhukhune) there is evidence that people are developing adaptation strategies to changing patterns of water availability and the ever-prevalent stress of limited finance, for instance some small scale farmers in Sekhukhune district have set up traditional food seed banks to help maintain food security and at the same time help curb climate change (GSDM, 2011). Farmers also plant traditional crops that require no chemical fertilisers or pesticides and they are drought resistant as well. However there is also an inability among farmers to understand potential impacts and to take appropriate action

before, during, and after particular consequences to minimize negative effects and maintain the ability to respond to changing conditions.

Climate change is costing communal farmers hundreds of lost livestock due to a lack of grazing and water shortages Limpopo province. Some farmers are now accusing the government of managing crisis instead of implementing preventative measures. They are also accusing government of not providing them with information on how to manage their livestock amid climate change. This is a very serious matter that needs a proactive approach on climate change to give all stakeholders information on how to manage this crisis.

Identification of adaptation strategies is very important especially for poorer and more vulnerable communities in Limpopo province. The following adaptation strategies were identified by Molope (2006) as vital for the Limpopo province: (a) Sustainable conservation practices such as reduced, minimum or no till in conjunction with crop rotation and multi-cropping to enhance soil health, (b) Use of baseline information already available such as national collections of insects, arachnids, fungi and nematodes to monitor the effect of climate change on biodiversity, (c) Continuous drought and heat to lerant crop development by both conventional breeding and biotechnology with emphasis on successful production in marginal areas, (d) Decision support systems to assist livestock farmers in handling the effect and consequences of adverse climatic conditions, (e) Investigation of the adaptive abilities of indigenous crops; water and rainfall use efficiency technologies to facilitate the principle of more crop per drop, (f) Climate change awareness campaigns to reduce the vulnerability of the people and to facilitate the adoption of water use efficiency and conservation ethics, (g) Evaluation of the significance of climate change relative to other contextual factors that confront development, (h) Development of predictive early warning models, biological control and integrated pest management techniques to ensure adaptive capabilities in view of changing pest and disease dynamics, (i) Early warning systems and risk and disaster management are pivotal and should constantly be developed and refined, (j) Awareness and adoption of water use efficiency to ensure storage in the soil and as little runoff as possible, and of rainwater harvesting technologies, (k) Water use efficiency and sustainability in irrigated agriculture, (l) Strengthening the social, economic and environmental resilience of the poorest and most vulnerable against climate change and variability, (m) Investigation and extrapolation of the suitability of crops in different areas in view of biofuel production.

By understanding, planning for and adapting to a changing climate, individuals and societies can take advantage of opportunities and reduce risks. As results of increasing variability of climate communities are being forced to change their ways of living in order to adapt: (a) growing different crops, (b) making better use of scarce water resources, (c) using different production methods, (d) or preparing for more frequent weather-related disasters. It should also be noted that adaptation to climate change is rooted in the local context and people's knowledge culture and values, as these will determine how they can best cope with change.

The aim of this paper is to identify the impacts and adaptation options of climate variability and change on agricultural production in Limpopo province. This will be guided by the following objectives: (a) To understand the impacts of climate variability and change on agricultural production in Limpopo province, (b) To assess the impacts of climate variability and change on agricultural production in Limpopo province and (c) To identify adaptation measures that could reduce the impacts of climate variability and change on agricultural production in Limpopo province.

2. Material and Methods

This paper used both quantitative and qualitative designs as questionnaire which included matters relating to climate change and agricultural production was used in the interviews and focus group discussions was conducted after face to face interviews with farmers. A temperature, rainfall and humidity parameters for the past 30-50 years for two selected districts was obtained from the South African Weather Services. Data on crops yield, tons, production and percent area planted for the past 30-50 years was obtained from the National Department of Agriculture. Permission was asked from the two district offices to conduct research in their different local municipalities. The following local municipalities were visited: *Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, LepelleNkumpi, Blouberg, Aganang, Polokwane and Molemoleas* seen in Table 1. The survey targeted three hundred farmers in Sekhukhune and Capricorn Districts as seen in figure 1. The two districts namely Sekhukhune and Capricorn were asked to provide the list of farmers in their municipalities.

Purposeful sampling technique was used to select three hundred farmers to be interviewed in order to cover uniformity and homogenous characteristics of farmers. The mixed questionnaire included matters relating to climate change and agricultural production were used in the interviews. Before the interviews start a village meeting was conducted with all community representatives present: chiefs, indunas, local councillors and NGO's.

The nature of the research and the contents of the questionnaire were explained to them. Focus group discussion was conducted after face to face interviews with farmers. Notes were also taken from observing the study areas.

Table 1: Summary characteristics of sample in 10 local municipalities

Variable	Total	Percentage
Number of Farmers per District		
Capricorn	167	56
Sekhukhune	133	44
Number of Farmers per Local Municipality		
Aganang	26	8.7
Blouberg	16	5
Polokwane	31	10
LepelleNkumpi	51	17
Molemole	43	14.3
Greater Tubatse	22	7
Makhuduthamanga	20	6.7
Fetakgomo	31	10.3
Ephraim Mogale	52	19
Elias Motsoaledi	8	2.3
Sex of Farmers		
Male	136	46
Female	164	54
Total	300	100

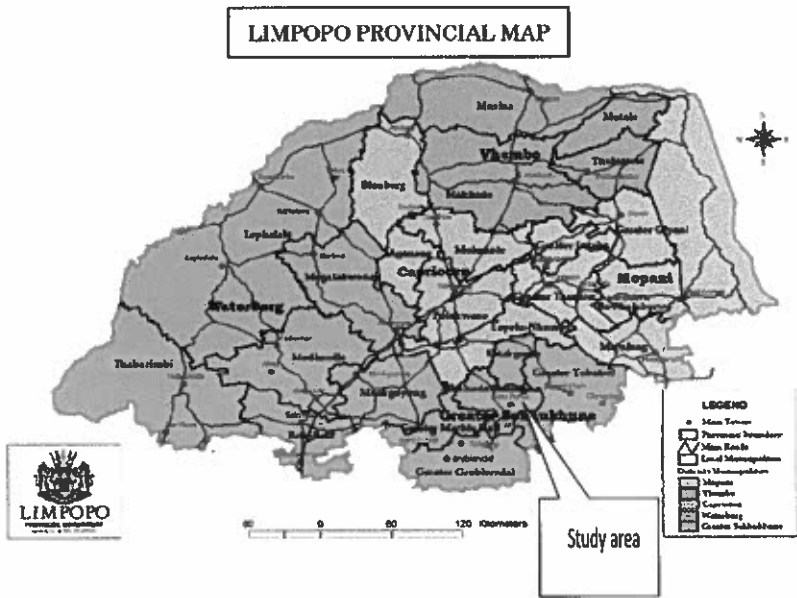


Figure 1. Geographic location of the Greater Sekhukhune district, Limpopo Province (StatsSA, 2006)

2.1 Univariate Analysis Model

According to Deressa et al. (2009), Univariate analysis is able to demonstrate the relationship between dependent and independent variables as stated in the general equation below:

Wi= _ + _Xi+ _i (1)

2.2 Multivariate Analysis Model

The application of multivariate analysis depends on many factors such as nature of variables used, research question, experimental design etc (Deressa et al., 2009). The equation can be written as follows:

$$Wi = _ + _1INFCi + _2ADCi + _3INFEXi + _4SEXF_i \tag{1}$$

3. Results and Discussions

This section presents various adaptation strategies being used by some Limpopo province farmers in response to changing climatic conditions based on the survey. The adaptation strategies are grouped into Colds, Heat, Frost, Abnormal Wind and Hail; Extension Support; Drought; Rainfall; Temperature and Nematodes, Insecticides and Worms.

3.1 Colds, Heat, Frost, Abnormal Wind and Hail

Some farmers with resources are using the Dacom system, which is an environmental tool that foresees incoming weather change like frost, hot days, abnormal winds and colds. They also apply 8 mm water the night before frost to avoid excessive damage. Farmers also put nets around their crops to protect against colds, heat and frost as seen in picture 1. Tyre burning is also popular among resource poor farmers to protect their crops against cold. This burning of tyres serves as a blanket for crops like tomatoes during cold season. Farmers also diversify their crops to minimise total loss of production due to unforeseen weather conditions. Some farmers prefer to plant cotton during hot weather because of its resistance to hot weather. The selection of crops which are not damaged also serve as other farmers' adaptation measure which is available to them. Those with water adapt by irrigating crops the following day after weather damage. This has proven positive in some instances. Fertilisers are also applied after cold/hail/frost damage to revive production.



Picture 1. Nets/shades as adaptation measure against cold and heat conditions



Picture 2. Wood serving as adaptation measure against abnormal winds

Wood also serves as adaptation measure especially for tomatoes against abnormal wind as seen in picture 2. In some instances Germ tomatoes is preferred as it can grow well under cold weather conditions. Reducing of planting space is also used by some resource poor farmers against cold weather. This is used mostly by cabbage and spinach farmers, who believe that by reducing planting space, crops serves as blankets to each other during cold weather and this method is working very well.

3.2 Extension Support

Big companies like Lonmin in Limpopo province offered farmers with extension services. These farmers are also offered opportunity to attend skills development workshop regarding climate and agricultural issues. Government is also playing an important role in providing farmers with seeds, fertilisers, pesticides, skills training but they don't offer this to all affected farmers and some farmers needs support like labour, packaging, financial and harvesting assistance from government. Joint ventures/partnerships are also a good adaptation measure to deal with climate change. Here resource poor farmers partnered with skilled white commercial farmers in order to receive skill transfer, climate advisory information, technical, markets availability and infrastructural assistance. Some of the commercial farmers mentor and plough back their adaptation measures to resource poor farmers. Some commercial farmers even went extra mile to register other farmers at technikons or universities.

3.3 Rainfall

Dacom system is used to foresee incoming weather change like low and high rainfall in some parts of Limpopo province. The use of cultivars that is resistance to high/low rainfall is used by some well resourced farmers in Limpopo province. Few farmers as seen in figure 2 are using Dacom system to change planting dates in case of unexpected weather patterns. Through this Dacom system farmers can harvest too early not to lose product quality and they can also shift harvesting through day and night harvesting. But this is labour intensive since all products should be harvested before expected damage. Farmers also use clouds as an indicator for possible rainfall. When clouds are clustered and dark, for example, farmers know that they will have rain within short period of time. Wind direction is also used by some farmers as an indicator for possible rainfall. They believe that when wind came from the western side they would receive rain within 12 hours.

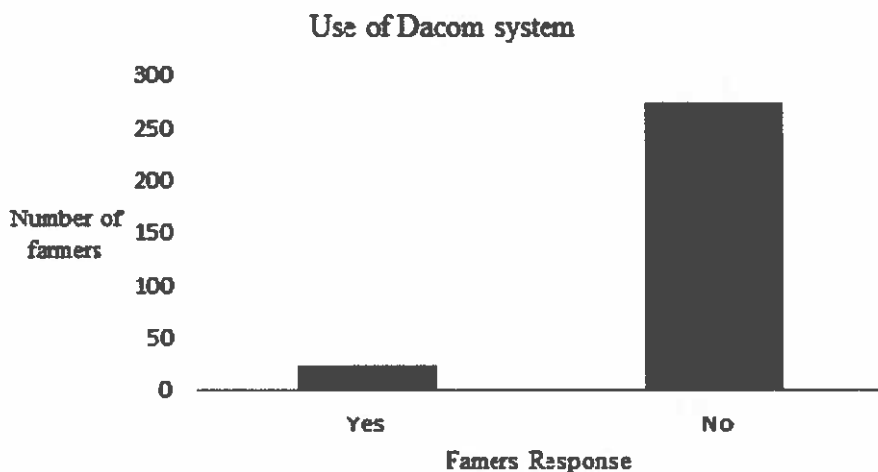


Figure 2. Use of Dacom system by Limpopo province farmers

3.4 Drought

Farmers in the area also developed drought-coping mechanisms and longer term research on the ecological, economical and social effects of drought. Some of the conservation practices used includes the following: (a) Minimum tillage; (b) Water harvesting; (c) Multi cropping and rotation practice; (d) Mulching system; (e) Rain gauge.

As shown in picture 3 minimum tillage is the low-impact system replacing ploughing which enhances carbon retention in soil. Minimum tillage is considered to be best management practice. The aim of this practice was to minimise soil disturbance and also retaining moisture throughout. This practice it also provides a wet season cover crop to protect the beds from slumping. Some of the advantages of minimum tillage includes: (a) better soil structure, (b) reduced soil loss and (c) reduced fuel costs. Picture 4 shows how rain water harvesting is practiced in the province. Water harvesting as indicated in picture 4 is when water is collected from the ground and this has achieved excellent results especial in some dry parts of Limpopo province. The primary reason to use this practice is to store available rainwater during the wet season and also to use the water for crop irrigation in the dryseason. This technique is also being practice in the Southern African Development Countries region due to its efficiency.



Picture 3. Minimum tillage practice by farmers in Limpopo Province

Source: ARC-ISCW (2007).



Picture 4. Water harvesting and optimization practice by farmers inLimpopo Province and other parts of the country

Source: ARC- ISCW (2007).

Crop rotation and multi cropping has become very popular in some dry parts of Limpopo province. As indicated in picture 5, crop rotation contributes to diversification of crop species and decreases the of diseases and pests attack. Greater nutrient utilization, less use of pesticides, and improved soil quality may reduce the overall environmental impact of crop production. The other preferred practice is multi cropping, which is the practice of growing two or

more crops in the same space during a single growing season and can reduce the risk of total loss from drought or pests. As shown in picture 6, mulching is essential to the survival of crops during drought periods. Mulch will reduce the amount of water that evaporates from the soil. Mulching improves the quality of the soil by breaking up clay and allowing better water and air movement through the soil. The benefits of this practice includes conserving moisture, slowing flood waters, slowing climate variability and change, lessening the need for pesticides, healthier crops and smothering weeds.

Due to drought some farmers established ventilation points in the soil for water to evaporate. A rain gauge as seen in picture 7 is also used by some farmers to measure the amount of rainfall. The data from rain gauges are especially important for farming in order to make decisions about crop planting (UNEP, 2008). In order to adapt against drought some farmers have water all the time as a measure of adaptation. They have good irrigation systems like centre pivots, drips and dams. Latest machines to take water to the fields are also available while some have boreholes and water underground.



Picture 5. Multi cropping and rotation practice by farmers in Limpopo Province and other parts of the country
Source: ARC-ISCW (2007).



Picture 6. Mulching system practiced by framers in Limpopo Province and other parts of the country
Source: ARC-ISCW (2007).



Picture 7. Environment monitoring tool-rain gauge

3.5 Temperature

The dacom system is being used by farmers with resources as adaptation measure against increased temperature. This basically helps farmers to monitor temperature levels in the soils. They also have fertilisers and chemicals to use against unacceptable temperature levels. Some resource poor farmers rely on friends, fellow farmers to establish temperature levels.

3.6 Nematodes, Insecticides and Worms

The well resourced farmers in Limpopo province are using chemical agents from reputable agrochem companies for dealing with nematodes, insecticides and worms. They use nemamate as a chemical to prevent nematodes infestation and if damage has already occurred they use nemacur. Most farmers emphasised the reading of recommendation as very important. Resource poor farmers plant onions alongside other crops to kill insects and worms. In this way onions kill insects and worms through its smell. This adaptation measure is more effective and positive results are achieved.

4. Summary and Conclusion

Important adaptation options being used by farmers were also discussed in this paper. This included different adaptation measures against colds, heat, frost, abnormal wind, hail, lack of extension support, nematodes, insecticides, worms, temperature and rainfall. As mentioned earlier, Limpopo province farmers have low capacity to adapt, it was interesting to observe some farmers using indigenous coping strategies like burning of tyres to adapt. So supporting these coping strategies of local farmers will help increase the adoption of adaptation measures thus bringing great benefits to vulnerable farmers in Limpopo province. According to DAFF (2011) there is sufficient evidence in South Africa to confidently predict that yields for certain crops will increase in some areas and decrease in others, while certain previously climatically unsuitable areas for specific crops will become suitable and vice-versa. Current maize production areas in the west of the country could become unsuitable for maize production due to increased rainfall variability (DAFF, 2011). Marginal land will become prone to reduced yields and crop failure because of diminished soil productivity and land degradation. Evidence also suggests that small-scale and urban homestead dry-land farmers are most vulnerable, and large-scale irrigated production is least vulnerable to projected climate change, given sufficient water supply for irrigation (IPCC, 2011). The government of South Africa has also outlined key adaptation measures to be taken against climate change across all its nine provinces (DEA, 2011).

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APPENDIX K: PAPER PRESENTATION

**50th Annual Conference of the Agricultural Economics Association of South Africa
(AEASA)**

01-03 October 2012

**University of Free State,
Bloemfontein**