IMPACT OF CLIMATE CHANGE AND ADAPTATION ON CATTLE AND SHEEP FARMING IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA

by

BUSISIWE MANDLENI

Submitted in accordance with the requirements for the degree of

Doctor of Philosophy
in the subject

Environmental Management

at the

UNIVERSITY OF SOUTH AFRICA

Supervisor: Prof F.D.K ANIM

October 2011

DEDICATION

This thesis is dedicated to my late father Garvey Gubuze Nkonki who left a legacy of education in my family and to my mother Constance Nosizwe Nkonki who has never failed to give me words of wisdom, prayers, moral and emotional support.

DECLARATION

I, Busisiwe Mandleni, declare that "IMPACT OF CLIMATE CHANGE AND ADAPTATION ON CATTLE AND SHEEP FARMING IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNED DATE: 14 October 2011

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Name: Busisiwe Mandleni

Student number: 45959765

ACKNOWLEDGEMENTS

I would like to show my gratitude to the Lord Almighty who is the author and finisher of our faith. Without Him, I would not be able to complete this study.

I am heartily thankful to my promoter, Professor FDK Anim, whose encouragement, guidance, constructive criticism and support, from the initial to the final phase, enabled me to develop an understanding of the subject. My sincere thanks also go to Professor Modise, Professor Awofolu and Dr Kayoka-Kabongo for supporting me all the way. I am also grateful to my colleagues for their academic support.

It is a pleasure to thank people of the Eastern Cape area of study who made this thesis possible i.e. the communities of the three districts; OR Tambo, Amathole and Chris Hani that were interviewed, the Department of Agriculture and extension officers.

I owe my deepest gratitude to my husband Ndedi and our two children Musa and Sinqobile for their patience and understanding when I spent week-ends in the office, and missed Sunday lunches.

It is a my greatest pleasure to pay tribute to my mother Constance Nosizwe, my four brothers Sonwabo, Mlungisi, Siyabulela, Lufefe and my three sisters Nosipho, Andiswa and Thando for their encouragement and believing in me.

May the Lord richly bless you all!

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ABSTRACT

This study focused on the impact of climate change and adaptation on small-scale cattle and sheep farming in the Eastern Cape province of South Africa. Using information from 500 livestock farmers between 2005 and 2009 farming season, three methods of analysis were used to determine impacts of climate change and adaptation. They were Principal Component Analysis (PCA), Binary Logistic Regression Model (BLRM) and Heckman Probit Model (HPM). Findings revealed that cattle production decreased during the study period 2005 to 2009. Preliminary descriptive statistics results indicated that farmers had different perceptions on climate change and adaptation measures between the periods 2005 and 2009. Further analysis using PCA showed that the different perceptions could be grouped into: (i) drought and windy weather patterns; (ii) information and adaptation; (iii) climate change extension services; (iv) intensive cattle and sheep production; and (v) temperatures. The results of the BLRM indicated that the most significant factors that affected climate change and adaptation were: (i) non-farm income per annum; (ii) type of weather perceived from 2005 to 2009; (iii) livestock production and ownership; (iv) distance to weather stations; (v) distance to input markets; (vi) adaptation strategies and (vii) annual average temperature. From the HPM the results indicated that marital status, level of education, formal extension, temperatures and the way in which land was acquired, significantly affected awareness on climate change. Variables that significantly affected adaptation selections were gender, formal extension, information received on climate change, temperatures and the way in which land was acquired.

It was concluded that in the area of study, change in climate was already perceived by small-scale cattle and sheep farmers. Households that perceived differences in seasonal temperatures during the survey period were less likely to adapt to climate change. Having access to extension services increased the likelihood of adaptation to climate change. Information on climate change to improve livestock production appeared to play a significant role in the selection of adaptation measures. The recommendation was that government should consider cattle and sheep farmers' perceptions on climate change when deciding on programmes for cattle and sheep production. It further suggested that the most significant factors that affected climate change, adaptation, and awareness and adaptation selections be considered when adaptation programmes are planned.

Key words: Climate change, perceptions, awareness, adaptation, cattle and sheep farming, Eastern Cape province.

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LIST OF ACRONYMS AND ABBREVIATIONS

AgriSA	Agriculture South Africa
BLRM	Binary Logistic Regression Model
BPM	Bivariate Probit Model
CSIR	Council for Scientific and Industrial Research
CV	Coefficient of Variation
DPLG	Department of Provincial and Local Government
EMG	Environmental Monitoring Group
ENSO	El Nino-Southern Oscillations
FAO	Food and Agriculture Organisation
FIML	Full Information Maximum Likelihood
GCCC	Government Climate Change Committee
GCMs	Global Climate Models
GDP	Gross Domestic Product
GHA	Greater Horn of Africa
GHGs	Green House Gases
HPM	Heckman Probit Model
ICARDA	International Centre for Agricultural Research in the Dry Areas
IES	Institute for Employment Studies
IFAD	International Fund for Agricultural Development
Indigo-dc	Indigo development and change
IPCC	Intergovernmental Panel of Climate Change
MDGs	Millennium Development Goals
MLE	Maximum Likelihood Estimation
NCCC	National Climate Change Committee
NDA	National Department of Agriculture
PCA	Principal Component Analysis
PROVIDE	Provincial Decision-Making Enabling
S A I	South African Info
SANMCCA	South African National Networking Meeting on Climate Change Adaptation
SPSS	Statistical Package of Social Sciences

SSA	Statistics South Africa
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reductions
WANA	West Asia and North Africa
WSSD	World Summit on Sustainable Development

CHAPTER 1

INTRODUCTION

"Ignoring climate change will be the most costly of all possible choices, for us and our children"

Peter Ewins (2011)

1.1 Background

Climate change is global because it affects all countries in the world. It is one of the biggest environmental challenges. It has become a major concern to society because of its potentially adverse impacts worldwide. There are already increasing concerns globally regarding changes in climate that are threatening to transform the livelihoods of the vulnerable population segments. The earth's climate has warmed on average by about 0.7◦C over the past 100 years with decades of the 1990s and 2000s being the warmest in the instrumental record (Watson, 2010).

Several views have been expressed by different researchers about climate change. Cruz *et al.* (2007) defined climate change as changes through increase in frequency and intensity of extreme weather events including storm, flood, drought and irregular rain over time and irregular climate signal. The Intergovernmental Panel of Climate Change (IPCC) Fourth Assessment Report (2007) forecasted that by 2100, the increase in average surface temperature would be between 1.8ºC and 4.0ºC globally. The panel predicted a more pronounced increase in temperatures in the African continent, to be 1.5 times greater than at the global level. Climate change is more pronounced in certain agro-ecological zones of the continents especially the interior. According to Tompkins and Adger (2004), climate change is likely to be manifested in four main ways: slow changes in mean climate conditions; increased inter-annual and seasonal variability; increased frequency of extreme events; and rapid climate change causing catastrophic shifts in ecosystems. It refers to gradual changes in climate norms, notably temperature, and changes in the frequency, extent and severity of climate and weather extremes (FAO, 2008).

Climate change is sometimes referred to as global warming because of the rising temperatures experienced across the globe. Global warming is the warming of the earth through increased Green House Gases (GHGs) that deplete the ozone layer. Global warming has been termed 'the greatest market failure the world has ever seen' (Stern, 2006). This is because the atmosphere is a global public good that any country can pollute. On the contrary, any country can benefit on efforts to ease pollution. A market failure then arises because the country that does not pollute cannot extract a payment for the benefit subsequently enjoyed by the country that pollutes.

The United Nations International Strategy for Disaster Reductions (UNISDR) projected global average surface warming to increase by 1.1 ºC to 6.4 ºC, sea level rise between 18cm and 59cm, the extreme heat waves and heavy rains that would be more frequent by 2050. The UNISDR also projected more intense hurricanes by that time (UNISDR, 2008). In the Polar regions, reductions in the thickness of glaciers has been predicted to cause a change in infrastructure and traditional ways of living among inhabitants. In Southern Europe, higher temperatures have been predicted to increase health risks and frequency of wildfires. In Asia, the continued melting of glaciers in the Himalayan region has also been predicted to increase flooding, especially in the heavily populated coastal areas. In North America, a decrease in mountain snow accompanied by increased flooding is expected to occur. Sustained higher temperatures are expected to increase the risk of forest fires. In the dry areas of Latin America, agricultural land is expected to be saline resulting in a decrease in the productivity of crops and livestock. In Australia and New Zealand, more frequent heat waves are expected to decrease water supplies and then affect agriculture and ecosystems negatively. Coastal areas are also expected to be flooded by 2050.

A study conducted in Europe confirmed that temperatures were most likely to rise across Europe especially in winter, and crop yields and their quality might be reduced resulting in the loss of rural household incomes. However, the study concluded that there were positive results that were expected from increased temperatures in some regions of Europe such as the Alpine, Boreal and the Atlantic. Studies have shown that increased CO_2 emissions may create some opportunities for new crops such as crops that require long growing periods. The study also indicated that there might be potential increase in livestock production in some agro-ecological zones although in other agro-ecological zones, livestock production might decrease (AEA Energy and Environmental group, 2007).

In the case of economic losses, an example is €15 billion loss in the United Kingdom and France. In Asia, 275 000 deaths due to flooding have also been experienced (Anderson and Bausch, 2006). Although there is some controversy on the reality of climate change, a lot of natural disasters in the form of floods, storms including hurricanes, extreme heat and drought have already been experienced in some parts of the globe (UNISDR, 2008). Examples of natural disasters are windstorms that were experienced in Europe at the end of 1999, and the major flood event that occurred in 2002. These disasters affected the economies of the countries concerned negatively.

There has been global concern that climate change might have negative effects on the economies of countries globally. That concern has called for the United Nations Framework Convention on Climate Change in 2009 that was held in Copenhagen, Denmark. The Convention encouraged the 37 industrialized countries and the European community to stabilize GHG emissions as they were perceived to be the countries responsible for high levels of emissions compared to other developing countries. Agriculture was considered among the factors that were not responsible for climate change as it contributed far less. Yet, the IPCC Fourth Assessment Report (2007) showed that agriculture directly contributed 13.5 percent of global GHG emissions. Deforestation contributed a further 17 percent and agriculture about one third of global GHG emissions. The interior of the earth's surface is predicted to have temperatures around 3ºC and the coast to be around 1ºC. By 2100, temperature increases are expected to approach 3ºC on the coast and 5ºC in the interior. The greater evaporation rates are expected to increase incidence and intensity of drought.

In the IPCC Fourth Assessment Report (2007), climate change was understood as any changes of climate over time due to natural changes. With this definition, climate change can be the resulting changes of internal processes or external forces (Nicholls *et al.*, 2007). According to FAO (2008), climate change refers to ongoing changes in the global climatic system, resulting primarily from anthropogenic global warming, as a consequence of increased and continuing emissions of GHG, and the loss of vegetation cover as well as other carbon sinks.

O'Brien *et al.* (2006) perceive climate change as the natural phenomenon that is accelerated by human activities. This is in agreement with the United Nations Framework Convention on Climate Change (UNFCCC) (2006) which referred to climate change as effects of direct or indirect human activities, leading to changes in global atmospheric components that create changes of natural climate variability observed over comparable time. The IPCC Fourth Assessment Report (2007) indicated that climate change was a reality and added that it was likely caused by human activities. According to the report, the GHG emissions in our atmosphere have increased since 1750 due to consumption of fossil fuels, new forms of land use, and agriculture. The report also stated that the increase in GHG emissions has led to an increase in average temperatures by 0.74 ºC since 1901. It also reported that scientists were 90 percent sure that the last half of the 20^{th} century has been the hottest period in the Northern Hemisphere in the past 500 years. The report further indicated that warming would be pronounced in northern latitudes for years to come, at least by 2050. Although the sun's radiation contributes to global warming, it has been found to be weaker compared to the contribution by human-induced global warming. Global rainfall patterns have also changed over the last century. There has been more rain in the eastern parts of North and South America, Northern Europe and Northern Central Asia than in any other parts of the world. The dry spells have been more frequent in Sahel, the Mediterranean, Southern Africa and parts of Southern Asia (IPCC, 2007). Preston and Leng (2008) also agreed to the burning of fossil fuels as major source of GHG emissions.

A consensus has emerged that developing countries are more vulnerable to climate change than developed countries because of the predominance of agriculture in their economies and scarcity of capital for adaptation measures (Fischer *et al*., 2005). A consensus has also emerged that it is likely that developing countries will be more vulnerable because a greater fraction of their economies is in climate sensitive sectors such as agriculture. Thomas and Twyman (2005) also asserted that developing countries are generally considered the most vulnerable to the effects of climate change than more developed countries, largely because of their often limited capacity to adapt to climate change. It is still the case that there is only limited knowledge about the interactions of climate with other drivers of change in agricultural systems and on broader development trends. Todaro and Smith (2009) also believed that the worst impact of climate change would be felt by the very poor although they made little contribution to climate change. Reid *et al.* (2007) claimed that poor nations would suffer the most from the effects of climate change because of their geographic locations in areas such as drought-prone sub-Saharan Africa or flood-prone Bangladesh. South Africa, being a developing country with agriculture dominating other sectors of the economy, is likely to be vulnerable to climate change. With its challenges such as less capacity to respond to climate change, which is characteristic of developing countries, it might not be an easy task to respond to climate change. Impacts of climate change in developing countries remain poorly understood because few studies have successfully measured the effects of climate on developing countries' economies.

The IPCC Fourth Assessment Report (2007) agreed to the certainty of climate change and added that it would be exacerbated with the passage of time with developing countries and the poorest, being the worst affected. In addition to global concerns, issues of the poor which were the key components of the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa, are an integral part of the Millennium Development Goals (MDGs) and feature in current poverty reduction strategies embraced by the World Bank and a majority of bilateral donors. Morton (2007) and Madzwamuse (2010) believed that climate change mostly affected developing countries, in particular among populations referred to as subsistence or smallholder farmers. Furthermore, small farm sizes, low technology and low capitalization are likely to increase vulnerability of livestock production. Water supplies from rivers, lakes and rainfall are threatened by climate change which reduces water availability for livestock production. De Wit and Stankiewicz (2006) calculated that decreases in perennial drainage would significantly affect present surface water access across 25 per cent of Africa by the end of this century. Arnell (1999) showed that the greatest reduction in runoff by 2050 would be in Southern Africa. This reduction in water supply indicates the significance of climate change.

In Africa, agriculture is negatively affected by climate change (Deressa *et al*., 2009). A study by Apata *et al.* (2009) concluded that Africa is generally a continent most vulnerable to climate change. This is due to the erratic and unreliable weather which calls for farmers to be aware of the effects that this weather pattern might have on farming in the immediate-term and long-term production periods. It also calls for adaptation measures that should be employed to curb the negative effects of climate change especially on livestock production. Thornton *et al*. (2002) forecasted that climate change was to bring about shortage of water which could reduce livestock feed and pasture yield. The study also forecasted that changes in rainfall patterns were likely to lead to outbreaks of livestock diseases such as bluetongue in Northern Europe and Rift Valley fever in East Africa. These diseases were estimated to bring about 20-30 percent losses of all plant and animal species. Furthermore, the quality of plant material was expected to be reduced due to increases in temperature thereby lowering the digestibility and degradation rates of plant tissues by livestock. This was likely to result in the reduction of livestock production impacting negatively on food security and incomes of households. Land use systems were expected to change resulting in changes in species niches which would also change animal diets and thereby compromising the ability of livestock farmers to manage feed deficits.

Extreme events such as floods, lightning, hailstorms and drought have been more frequent and intense in Africa over the past few years. Similar events have been experienced in South Africa with the Karoo being the hardest hit by drought. Such events are not good for the country's economy because there are associated costs. Extreme events are predicted to increase in many desert regions in Southern Africa (Scholes and Biggs, 2004). In Tanzania, the effects of climate change are already vivid. According to the United Republic of Tanzania Poverty and Human Development Report (2009), climate change threatens to undo the development achievements registered over the decades. The poor nations also have a lower response rate due to low capacity to cope with climate change compared to wealthier nations, because of limited financial resources, skills and technologies and high levels of poverty, which worsens the challenges of climate change.

Reid *et al*. (2007) made forecasts on economic impact of climate change in Namibia where the economy heavily relies on extensive livestock production activities both commercial and subsistence. The study predicted grassland shifts to forests as rainfall increased and an increase in precipitation would increase the incidence of diseases. On national income, the loss in livestock productivity was estimated to be between 20 and 50 percent. The economic impact due to climate change effects could be a decline in Gross Domestic Product (GDP) contribution which was estimated to be 4 percent to the whole economy.

Food and Agriculture Organisation (FAO) in 2007 estimated that approximately 20 to 30 percent of plant and animal species were expected to be at risk of being extinct by 2100. Higher temperatures were envisaged as well as changes in rainfall patterns which were expected to result in increased spread of existing vector-borne diseases and macro parasites of animals as well as the emergence and spread of new diseases. The FAO (2006) indicated that the effects would be felt by both developed and developing countries, but developing countries would be most affected because of their lack of resources, knowledge, veterinarian services, extension services and research technology.

Reid *et al.* (2007) reported temperature changes as indicated by long-term temperature records from weather stations in Namibia and the Northern Cape, which showed a mean decadal temperature increase of 0.2ºC. This is roughly three times the global mean temperature increase reported for the 20th century (Midgley *et al*., 2003). This warming is greatest over the interior of semi-arid margins of the Sahara and central Southern Africa. A more recent Global Circulation Model suggests that by the 2070-2099 period, maximum warming in Southern Africa is expected to be up to 7°C (Ruosteenoja *et al*., 2006).

Reid *et al.* (2007) also reported reduced precipitation in Southern Africa in the next 100 years as most models projected that by 2050, the interior of Southern Africa will experience significant decreases during the growing season as in the IPCC Third Assessment Report of 2001. The Southern African monsoon is projected to weaken during the 2000-2049 period; precipitation is expected to decrease; and by the 2080s, a drying over much of the western subtropical region (which includes northern Namibia) due to fewer rainy days and less intense rainfall is forecasted (Hudson and Jones 2002; Hulme *et al*., 2001; IPCC 2001; Ruosteenoja *et al*., 2006). Kigotho (2005) added that climate change that induced warming of the Indian ocean was likely to lead to persistent droughts in Southern Africa in the coming years, and the monsoon winds that brought seasonal rain to sub-Saharan African could be 10-20 per cent drier than 1950-2000 averages (IPCC, 2001).

In South Africa, since climate change is also a concern, studies indicate that climate change is already occurring (Archer, 2010) and Madzwamuse (2010). Examples of working groups on climate change are the Environmental Monitoring Group (EMG) and the Indigo development and change (Indigo-dc) whose purpose is to help affected communities improve the ability to respond effectively to climate change. Madzwamuse (2010) identified warming of between 1ºC and 3ºC and rising daily maximum temperatures in summer and in autumn in the western half of the country. According to Blignaut, *et al.* (2009), South Africa in general has been approximately 2 percent hotter and at least 6 percent drier over the ten years between 1997 and 2006 compared to the 1970s. Significant surface temperature is evident over the South and Southern parts of Africa as well as significant changes in rainfall variability (Archer, 2010).

Climate change can have adverse effects on the agricultural sector because agriculture depends on a specific pattern of climate in order for it to be productive. The agricultural sector in South Africa contributes 3.4 percent to the Gross Domestic Product (GDP) and employs 30 percent of the labour force (Dinar, *et al.,* 2008). Primary agriculture contributes about 3 percent to the GDP of South Africa whose nominal value was estimated at R667 billion for the third quarter of 2010, (Chamuka, 2011). It is also the earner of foreign exchange through exports of raw materials and agricultural products. Despite its contribution to the economy, this sector is affected by climate-related disasters such as floods and extended dry spells. Madzwamuse (2010) indicated that climate change reduced the contribution of agriculture to the GDP from 9.1 percent in 1965 to 4.0 percent in 1998. The most important factor is the awareness of the negative impacts climate change might have on cattle and sheep production in the Eastern Cape province and adaptation measures thereof.

We can also expect that the livestock systems based on grazing and the mixed farming systems will be more affected by climate change than an industrialized system. Thornton *et al.* (2009) in Notenbaert *et al.* (2010) observed climatic trends that included reduced productivity of animal feed, higher disease prevalence, and reduced fresh water availability. This was due to the negative effects of lower rainfall and more droughts on crops and on pasture growth, and of the direct effects of high temperature and solar radiation on animals. According to FAO (2009), livelihood systems are vulnerable to climate change. These systems include small-scale rain-fed farming systems, pastoralist systems and forest-based systems in locations where productivity declines are projected as a consequence of climate change. They also include low-income farmers, fishers and city-dwellers whose access to food and sources of livelihood are at risk from the impact of extreme weather events. The food security of persons belonging to these systems could be at increased risk, but this risk could be offset by the adoption of measures to strengthen resilience and sustainability in the face of a wide range of possible impacts of climate change (FAO, 2009).

Grazing livestock is expected to be negatively affected by climate change. According to (Madzwamuse, 2010), rainfall will be reduced and thereby reduce fodder production while increasing marginal costs of ranching. Most of South Africa, especially the drier part, is used for grazing by cattle, sheep and wildlife. By 2050, South Africa is expected to face water scarcity because it is experiencing frequent droughts and floods. Rainfall is highly variable in spatial distribution and is unpredictable. The expected 2ºC increase in temperatures is expected to increase average savannah fires by 7 percent and with the increase in grass fuel load of 15 percent, fire intensities are expected to increase by about 20 percent (Madzwamuse, 2010). Higher carbon dioxide is expected to lead to less protein in the grass, which will reduce any benefit resulting from increased plant growth. The reduced amount of rainfall is expected to affect fodder production and lead to proportionately less animal production. Climate change is also expected to increase the frequency and spatial spread of livestock disease outbreaks such as foot and mouth disease.

IFAD (2010) purported that neither adaptation nor mitigation can avoid all climate change impacts. To respond to this threat, it will be necessary to focus on awareness of climate change and adaptation in order to support local communities in dealing with the impacts of climate change. At present, very few development strategies promoting sustainable agriculture and livestock-related practices have explicitly included measures to support local communities to become aware and adapt to or mitigate the effects of climate change. Activities aimed at increasing rural communities' resilience will be necessary to support their capacity to become aware and adapt to climate change.

The MDGs as stipulated by the UN in 2000 are threatened because they might not be achieved in South Africa by 2015, as planned. The first MDG is to alleviate extreme poverty by 2015 by reducing by half the proportion of people living on less than a dollar a day and people who suffer from hunger. Agriculture, which is the primary hunger- reducing factor in developing countries, might be affected negatively. Erratic rains and extended periods of drought are likely to reduce livestock production due to the fact that fauna depends on water and grazing land. Nhemachena *et al.* (2008) also alluded to the view that the adverse effects of climate change on agriculture threaten efforts and progress made by programmes aimed at attaining the MDGs.

1.2 Problem statement

According to Cohen (2001), in 2050, the world population is expected to reach 9.3 billion and more than 60 percent will live in towns. Global meat consumption is expected to double during that period. Animal production therefore should increase at a global level in order to meet the growing need of livestock meat consumers. The challenge however, will be how to balance either the increase in the number of livestock or the productivity per head, at the same time, reducing carbon emissions that will be brought by livestock production. Another challenging factor is the billion land animals which are reared and slaughtered, which either directly or indirectly contribute to total human-induced GHG.

Climate change has been acknowledged to have negative impacts on agriculture in studies conducted in the African countries, Europe, USA and in other parts of the world. Forecasts about climate change in South Africa indicate that certain species of animals will become extinct as a result of climate change (Turpie *et al.,* 2002). Many rural residents practise agriculture with livestock production as the major production. There are about 94.7 percent of rural households that practise agriculture in the Eastern Cape province (PROVIDE, 2005).

Agriculture is the backbone of South Africa's economy and livestock production is predominant in most provinces of the country. Poverty levels are high in the rural areas where most people depend on livestock for their livelihoods. In the Eastern Cape, livestock production is considered to be a store of wealth and source of livelihoods. To an overwhelming majority of South Africans in rural communities, livestock production is also considered to be the store of wealth.

Eastern Cape is, however, the second poorest province in *per capita* income terms, (SSA, 2003) when compared to the other eight provinces of South Africa. It would therefore be important to study perceptions of cattle and sheep farmers on climate change. It would also be critical to study adaptation measures that farmers employ in order to deal with climate change. The extent of awareness of climate change is critical together with exploring adaptation measures, followed by factors that affect adaptation measures and factors that influence awareness and decisions to adapt to climate change. Adaptation measures are very important because they are meant to save cattle and sheep production in the province. The South African National Networking Meeting on Climate Change Adaptation (SANMCCA) identified gaps and shortcomings in adaptation in all provinces of South Africa. The prominent gaps and shortcomings identified were rural bias in projects whereby focus was at national level, lack of voice from civil society, government failure to integrate activities and minimum contribution from research.

There is very little literature about climate change effects on livestock production in South Africa. The existing literature covers only few crops (Schulze, 1993; Du Toit *et al*., 2001; Kiker 2002; Kiker *et al*., 2002, Benhin, 2006). Despite the importance of livestock production for the economy of South Africa, very little or not enough information or study exists on climate change and its effect on livestock production. This study is intended to fill in the gap in the literature by examining the impact of climate change on cattle and sheep production in the Eastern Cape province using household-specific cross-sectional survey data. The study is also intended to focus on sheep and cattle production due to their predominance (Table 1.1) and importance as assets and wealth to farmers in the province.

Table 1:1: Cattle and sheep numbers by province.

Province	Cattle	Sheep
Western Cape	532 000 (3.81%)	2 640 000 (10.76%)
Northern Cape	485 000 (3.47%)	6 222 000 (25.38%)
Free State	2 324 000 (16.67%)	4 892 000 (19.95%)
Eastern Cape	3 183 000 (22.80%)	7 313 000 (29.83%)
Kwa Zulu-Natal	2 935 000 (21.05%)	810 000 (3.30%)
Mpumalanga	1 412 000 (10.13%)	1 703 000 (6.94 %)
Limpopo	1 026 000 (7.36%)	204 000 (0.83%)
Gauteng	270 000 (1.93%)	90 000 (0.36%)
North West	1 770 000 (12.70%)	639 000 (2.60%)

Source: NDA (2008)

1.3 Research objectives

The main objective of the study is to provide the reader with an overview of how cattle and sheep farming in the Eastern Cape is affected by climate change, and adaptation measures employed by the cattle and sheep farmers. The objectives of the study are as follows:

(i) Examine perceptions of cattle and sheep farmers on climate change and adaptation with the use of information from livestock farmers between 2005 and 2009 farming season;

(ii) Investigate factors that affected choices of adaptation by households who kept cattle and sheep;

(iii) Establish the extent of awareness of climate change in the area of study and to select livestock producers that were aware of climate change from a pooled sample of 250 respondents. This would be followed by isolating livestock farmers that adapted to climate change from the group that was aware of climate change, and to identify adaptation measures that they adopted.

1.4 Significance of the study

There is an urgent need for communities on a global scale to understand the concept of climate change and the dangers of climate change. Communities in general need to understand that climate change is here for them to do something about it. Governments also need to understand dangers that climate change have and will have in the future. The poor communities are more vulnerable to climate change because they do not have resources to deal with climate change. Governments have an obligation to save its communities from the negative effects of climate change.

Affected communities should be persuaded to understand that in order for them to survive climate change, they need to adapt to climate change and respond effectively, hence they cannot avoid it. Adaptation option is a better way so far in order to deal with climate change than mitigation in developing countries. Therefore, adaptation measures should help communities deal with climate change. The IPCC (2007) defined mitigation as: "An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases." The IPCC (2007) defined adaptation as the "adjustment in natural or human systems to a new or changing environment". Adaptation to climate change refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation measures can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (Klein *et al.,* 2007). Therefore, adaptation measures will be a better option for developing countries including the area of study, because they are more vulnerable due to widespread poverty and can lack the ability to respond. Developed nations are generally better equipped, educated and resourced to be able to deal with climate change.

In the Eastern Cape province, cattle and sheep farmers should understand better the concept of climate change. They should be cognisant with factors that prevail during climate change and affect cattle and sheep production. Knowledge of adaptation options and preparedness for climate change is crucial for the livestock farmers. The study should make recommendations on adaptation strategies and mechanisms to deal with climate change for cattle and sheep farmers.

1.5 Outline of the study

Chapter 1 provides background on climate change as the world's biggest threat. It provides the problem statement and research objectives of the study. The significance of the study is pointed out together with the outline of the study.

Chapter 2 focuses on how agriculture in international countries, African countries and South Africa is affected by climate change. The chapter further explores how countries perceive climate change and how they adapt to climate change. Lastly, the chapter focuses on livestock production in South Africa, how it is affected by climate change, and the adaptation measures employed to curb the negative effects of climate change.

Chapter 3 presents the area where the study took place, sample selection method and the way in which data was collected. Method of data analysis is also described.

Chapter 4 examines perceptions of cattle and sheep farmers on climate change and adaptation in the Eastern Cape province of South Africa. It is intended to verify whether the cattle and sheep farmers have observed any changes in the weather patterns and if they adopted any adaptation measures.

Chapter 5 investigates the factors that affect the choices of adaptation by households who keep cattle and sheep.

Chapter 6 explores the extent of awareness of climate change by cattle and sheep farmers in the study area. It further investigates the choice of adaptation measures that they follow together with the factors that affect adaption measures.

Chapter 7 summarises, concludes and makes recommendations based on the findings of the study.

CHAPTER 2

LITERATURE REVIEW

Climate change affects us all, but it does not affect us all equally. The poorest and most vulnerable –those who have done the least to contribute to global warming—are bearing the brunt of the impact today". Ban Ki-Moon (2009)

2.1 Introduction

This chapter first reviews the impact of climate change globally, in African countries and in South Africa. The impact can be explained in terms of extreme weather events, unpredictable temperatures as well as projections of the effects on agriculture and on livestock production. This chapter also focuses on the impact of climate change on livestock production, the contribution of livestock to climate change as well as to the environment. In addition, challenges for poverty alleviation are explored. This chapter further explores how countries perceive climate change and how they have adapted to it. Perceptions differ from country to country and some perceptions are based on beliefs and norms. Also mentioned is that adaptation measures are not the same throughout the areas studied. This chapter further discusses adaptation of livestock to climate change. Lastly, the MDGs in relation to climate change and livestock production are explored.

2.2 Climate change

Extreme weather events are now on the rise worldwide and are more likely to happen in the future (Easterling *et al.*, 2000). These are predicted to be characterized by extreme droughts and very wet periods due to flood events. Extreme precipitation events have become the order of the day. The number of areas that are affected by extreme drought and excessive rains are increasing. There have been storms across the globe with very few areas that have not been affected. The affected areas have had devastating effects on livestock production as well as on the economies of many countries. The worst affected areas are those with poor infrastructure and such disasters have led to high economic costs. Disasters have imposed high costs in South Africa, since most people live in marginal lands that tend to be fragile and subject to natural disasters. Moreover, since most livestock productive capacity in South Africa takes place in fairly confined areas, which are often vulnerable to drought and heavy rains, the potential losses due to such disasters have been quite significant. The disasters have been accompanied by lightning that has resulted in many livestock deaths.

In the same vein, drought is also a damaging factor that a country can face, since it affects livestock production. The most vulnerable are always the poor because they do not have the means to deal with the negative effects of drought. Drought has affected America, Europe and Africa in the last decade, and the 2003 drought and heat waves in Europe led to significant damage in terms of livestock productivity and mortality. Ciais *et al.* (2005) asserted that the total eco-system productivity as well as total carbon sequestration in Europe decreased due to the recent drought conditions. Forests were affected, tree damage increased markedly, and net carbon sequestration dropped.

The world's climate is continuing to change at rates that are projected to be unprecedented in recent human history. The global average surface temperature increased by about 0.6 °C during the twentieth century (IPCC Third Assessment Report, 2001). According to the Fourth Assessment Report by Inter-governmental Panel of Climate Change (2007), most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. The IPCC climate model projections from 2001 suggest an increase in global average surface temperature of between 1.4 to 5.8 °C to 2100, the range depending largely on the scale of fossil-fuel burning between now and then and on the different models used. At the lower range of temperature rise (1 to 3 °C), global food production might actually increase but above this range, would probably decrease (IPCC Fourth Assessment Report, 2007).

According to Rischkowsky *et al.* (2004), recent climate change scenarios showed that most of the Near East region would face a decrease in water availability by up to 40 mm per annum. Crop water availability was expressed as runoff which can be defined as the difference between rainfall and the sum of evapo-transpiration. The climate change scenarios took into account both rainfall and temperature patterns, including the effect of increased temperatures on increased evapo-transpiration. The number of dry days were expected to increase everywhere in the region, with the exception of some central-Saharan areas, while the number of frost days were expected to decrease everywhere. The length of growing seasons was also expected to decrease once temperature increases reached 3 or 4°C. Yields of the key crops across Africa and Western Asia were predicted to fall by 15 to 35 percent or by 5 to 20 percent, depending on whether there is weak or high carbon fertilization (FAO, 2008). The expected additional stresses from climate change in most of the region were expected to increase the already evident vulnerability to climatic fluctuations in West Asia and North Africa (WANA) region (Rischkowsky *et al.,* 2004).

Lars *et al*. (2009) used an ecological-economic model to explore the local, economic impacts of climate change in the Sahel. The results of the model indicated that changes in average annual rainfall or rainfall variability were expected to have a strong impact on the livelihood of the pastoralists in the Sahel. Both the overall profits from livestock keeping, and the per hectare income that could be obtained from this sector would be reduced in case of lower rainfall. For example, the model indicated that a 15 percent decrease in rainfall combined with a 20 percent increase in rainfall variability would lead to a 15 percent reduction in the open access stocking density, and a 30 percent reduction in the optimum stocking density. The model also showed that, through reduction of the overall stocking density, part of the negative impacts of rainfall reductions could be mitigated.

Thomas and Twyman (2005) argued that the expected impact of climate change on agriculture had to be seen on the background of other trends shaping the agricultural environment in general. Examples of such trends that were highlighted were growing populations, continued reliance on income from agriculture and unstable off-farm income due to political and socio-economic factors. Other important additional trends interacting with the impact of climate change production included land desertification, decreasing productivity of ranges and reduction of land devoted to livestock production or production of fodder. This negatively affects livestock production which in turn adversely affects household livelihoods.

In the tropics and subtropics in general, crop yields have been predicted to fall by 10 to 20 percent in 2050 because of warming and drying, but there are places where yield losses may be much more severe (Jones and Thornton, 2003; Thornton *et al*., 2009). Furthermore, in the tropical and subtropical regions, livestock production seems to be threatened by heat stress. It is predicted that livestock production in developing countries will continue to sustain future world growth of pig production despite the many challenges faced in developing countries including price of imported raw materials, economic crisis and environmental problems. However, in the tropical regions, livestock production and performance remain generally lower than those that are in temperate countries, in Western Europe and North America. This is attributed to limiting climatic factors that reduce production efficiency in these warm regions.

Mexico, like many developing countries, has a potential to be vulnerable to economic damages caused by global climate change. Its development level is low in such a way that it has not yet made the investments required to protect it from extreme weather events. The presence of large-scale poverty and a highly skewed income distribution exacerbates the situation and increases vulnerability of certain areas to weather related disasters. Its geographic position is directly related to a relatively high probability of being hit by hurricanes and tropical storms. Because it has a dry climate in the northern regions and very wet areas to the south, climate change is likely to increase the frequency and intensity of hurricanes and extreme precipitation events together with higher temperatures. These events increase Mexico's vulnerability to natural disasters.

According to Liverman and O'brien (1991), Mexico is particularly prone to suffer at least two different types of these events such as droughts and hurricanes. The reason is that it is a developing country and developing countries have the majority of their economic activities based on agriculture. The World Bank, through its Hazard Management Unit, studied earthquakes, volcano eruptions, floods, droughts, and cyclones and discovered that Mexico ranked 32 among the 60 countries affected by two or more potential hazards. Mexico is predicted to be likely to face repeated disaster-related losses and costs, leading to recurrent granting of financial relief to regions hit by such events.

Liverman and O'brien (1991) again conducted a study on climate change in Mexico. The study looked at the effects of an extended drought on the Mexican economy. The study also focused on the effectiveness of several adaptation strategies in the agricultural and forestry sectors. As expected, the study discovered that the largest production losses occurred in the rural sectors with output in livestock dropping by 13.78 percent. Smaller losses occurred in urban areas since declines in the manufacturing sectors (i.e. manufacturing, chemicals, refining, and electricity) were, by and large, less severe than in agriculture, while the service sectors (i.e. service and transport) hardly suffered any losses at all. The results also showed significant linkages between sectors and consumers, and rising food and energy prices combined with an influx of workers from drought affected areas that would put a strain on urban facilities. The study concluded that since agriculture was relatively more important to the lower-income groups, drought would have a damaging regressive impact on consumer welfare.

An understanding of the connection between climate on one hand and livestock production on the other, is of great importance if economic growth is to be sustained in developing countries. In Southern Africa in general, as in many other parts of the continent, the probability of occurrence of extreme events is predicted to increase, and one manifestation of this is changes (increases, often) in the year-to-year variation in rainfall. The impacts of climate change are predicted to be different from one area to the other as manifested in this study. There is consensus from a suite of different models that precipitation increases are very likely to occur in high latitudes, while the tropics and subtropical land regions are likely to see decreases in most areas (IPCC, 2007). The combination of generally increasing temperatures and shifting rainfall patterns will clearly have impacts on livestock production. Feed is predicted to remain a critical constraint on livestock production in the tropics and crop productivity is a useful proxy for feed availability in most regions. At mid to high latitudes, crop productivity may increase slightly for local mean temperature increases of up to 1-3°C, depending on the crop, while at lower latitudes, crop productivity is projected to decrease for even relatively small local temperature increases (IPCC, 2007).

According to IPCC (2007), it is likely that the climate change will alter the regional distribution of people dependant on livestock production. Large negative effects are expected in sub-Saharan Africa. Smallholder farmers, subsistence farmers together with pastoralists are expected to suffer complex and localised impacts of climate change, which will be due to both constrained adaptive capacity in many places and to the additional impacts of other climate-related processes. Climate change impacts on agriculture are thus not only regionally distinct but also highly heterogeneous spatially. Increasing frequencies of heat stress, drought and flooding events are estimated to be likely, even though they cannot be in any satisfactory way with current levels of understanding of climate systems, but these will undoubtedly have adverse effects on crop and livestock productivity over and above the impacts due to changes in mean variables alone (IPCC, 2007).

Thornton *et al.* (2002) indicated that out of the planet's 1.3 billion poor people, at least 90 percent of them are located in Asia and sub-Saharan Africa. About 60 percent of these poor people depend on livestock for some part of their livelihoods. Climate change is likely to have major impacts on poor livestock keepers and on the ecosystem goods and services which they depend on. These impacts will include changes in the productivity of forage, reduced water availability, more widespread water shortages, and changing severity and distribution of important human, livestock and crop diseases. Major changes can thus be expected in livestock systems, related to livestock species and feed resources.

There is now a general concern that climate change and increasing climate variability will compound the already existing developmental challenges. One approach to making sense of the interactions of broad development drivers, with the added burdens of climate change, is scenario-building and analysis (MEA, 2005; ILRI-FAO, 2006). Such work is very difficult, given that the future is relatively unknown, but it is increasingly important as one method to evaluate how farming systems may evolve in the future, sometimes very rapidly. Part of this work necessarily involves trying to understand the likely impacts of climate change on vulnerable people through its effects in and on other sectors. These include impacts on water resources, livestock and human health.

Bockel and Smit (2009) on the draft version of policy guidelines, identified climate change impacts which were a shift in agro-climatic zones and changes in the suitability of land for different types of pastures. They predicted that a rise in sea level would inundate agricultural areas and/or lead to saltwater intrusions, thus precluding the use of certain areas for livestock production. They also predicted an increase in temperature in most places which, according to them, were to decrease precipitation, alter evaporation processes, affect water supplies, alter the seasonality of extremes as well as a decline in crop yields (and some increases), reduce production and revenues, and stress on livestock, compounded by diseases and lower livestock productivity. The increase in temperature coupled with a decrease in precipitation was foreseen to seriously reduce productivity and constrain livestock production. The positive aspect predicted about the change in climate was that precipitation increases would result in crop yield gains with associated benefits for production and incomes. Conversely, precipitation decreases were predicted to lead to crop losses, diminished production and reduced revenues, constrained livestock production and moisture deficits. At the same time, the increase in floods and droughts were predicted to lead to livestock losses, disease outbreaks, and destruction of infrastructure, hunger and displacement of people.

A study conducted by Kurukulasuriya *et al*. (2007), used the Ricardian technique to estimate possible impacts of climate change in Sri Lanka. The results suggested that climate change had significant impacts on smallholder profitability. Impacts varied across geographic areas, from losses of 67 percent to gains of more than double revenues. The largest adverse impacts were anticipated in dry areas of North Central region and dry zones of South Eastern regions of Sri Lanka. The study also found out that intermediate and wet zones were likely to benefit livestock farmers mostly due to predicted increase in rainfall.

Slater (2007) conducted a study which focused on impacts of climate change on natural resources, transportation and infrastructure, commodity prices, access to markets, agriculture growth and role of state. The study discovered that precipitation in semi-arid and arid developing world was highly variable and degradation of the natural resources base had increased. The study also found out that infrastructure was threatened by disasters such as floods. As a result, transport costs were expected to increase through shipping and airfreight as this had implications on global and local competitiveness. The study also predicted that global prices for commodities could increase although there would be significant inter-regional differences. Price volatility was predicted to increase. Changing consumption patterns and increased transport costs were expected to reduce access to supermarkets in developed countries.

Different simulation models to assess socio-economic and climate change impacts on agriculture for the period 1990 to 2080 globally, indicated a decline in cereal production and consumption as well as an increase in the number of people at risk of hunger (Fischer *et al.,* 2005). On the contrary, the results of a study conducted by Deschenes and Greenstone (2007) on the impact of climate change on the US Agricultural land, indicated an increase in annual profits by 4 percent in the agricultural sector. Moreover, the results did not indicate any effects on yields among the most important crops i.e. corn and soybeans, which suggested that small effect on profits were due to short-run price increases.

FAO (2009) anticipated that climate change will threaten food security which can be defined as physical and economic access to sufficient, safe and nutritious food by all people at all times to meet their dietary needs and food preferences and a healthy lifestyle. Food security has been found to be threatened by increased temperatures that cause heat stress to plants, increasing sterility and thereby lowering overall productivity. Heat also reduces water availability. The unavailability of plants should have a negative impact on livestock production because livestock depends on pastures in order to survive. The unavailability of water also impacts on livestock production which needs a lot of water for drinking, dipping and other health-related aspects. Climate change is also expected to shift the ecological niches as rainfall is becoming unpredicted and unreliable in terms of timing and volume. This scenario leaves livestock producers in a dilemma in terms of how to change production patterns in order to align them with the changing weather patterns. This cannot be an easy task for livestock producers because moving livestock from one region to the other in search of good pastures has negative implications.

Anderson and Bausch (2006) provided scientific evidence on links between extreme weather disasters and climate change in Europe. Examples of weather-related disasters were rising average temperatures since 1900. The magnitude of the rise in mean temperatures and the existence of severe extremes were inconsistent with natural cycles. This is consistent with influence on human induced GHGs. More examples were intense precipitation and increased drought and hurricanes.

Mader *et al.* (2009) used models to study potential climate change effects on warm season livestock production in the Great Plains of the United States of America. The study was based on confined swine, beef and milk producing cattle on climate change projections in daily ambient temperature. Results of analysis indicated projected economic losses for livestock production to increase in most cases during summer period. A similar study by Nardone *et al.* (2010) on the effect of climate change on animal production and sustainability of livestock systems, discovered that a relevant increase in drought should be expected across the world which will affect forage and crop production. The heat was predicted to impair productivity i.e. milk yield and quality, meat quality and egg yield, metabolic and health status of livestock. Desertification was expected to decrease carrying capacity of rangelands resulting in poor nutrition of livestock, poor animal health and mortality of calves.

In Africa, there are also studies that have been conducted to estimate potential impacts of climate change. Hassan (2010) used the Ricardian method to study potential impacts of climate change on agriculture in 11 African countries. The study concluded that warming was harmful to crop production but beneficial to crop production under irrigation. For livestock, warming appeared to be harmful to large-scale while beneficial to small-scale livestock. The reason for this could be that large-scale livestock had lower tolerance to high temperatures, whereas small-scale had higher tolerance to high temperatures as they were local breeds.

Studies conducted in Kenya, indicated that there was a special relationship between women and livestock production. Poor women could own livestock when they were denied land although men had far greater numbers of livestock than women. The reason given was that, looking after livestock fitted well with their daily programme of running households chores. Richards and Godfrey (2003) reported on a study conducted in Kenya that focused on the importance of urban livestock. The study reported that the erosion of the material base had been exacerbated due to an adverse climatic trend in the region, which had increased the incidence and duration of drought and therefore, bringing diseases to livestock. Households that could not afford pastoralism, suffered losses of livestock and had to seek supplementary or alternative sources of income. Subsequent results were migration and part-time cultivation as well as shift to agro-pastorals. These developments had serious impacts on women pastoralists, as most of them had little say in their communities' decision-making, and few had rights to land.

Oseni and Bebe (2010) conducted a study that investigated options and strategies for reducing vulnerability and building resilience among farmers in Kenya. The design of intervention measures for climate change adaptation for the communities were found to be affected by comprehensive knowledge of the overall structure and dynamics of livestock production systems, including key information about indigenous breeding strategies relating to animal adaptation and management in climate sensitive dry-lands. The study revealed that the harsh effect of climate change was expected to have maximum impact on vulnerable pastoral communities engaged in extensive livestock production systems in dry-lands of Kenya.

Molua (2008) also conducted a study on the impact of climate change on Cameroon's agriculture and the results indicated that 3.5 percent increase in temperature and 4.5 percent increase in precipitation in the absence of irrigation facilities would be detrimental to Cameroon's agriculture, leading to a loss of 46.7 percent in output value. This loss was predicted to negatively affect the economy of the country as a whole since close to 30 percent of the country's national GDP came from agriculture. Molua (2009) made a similar study on climate change effects on smallholder agriculture of Cameroon. With the use of the Ricardian method, he discovered that the increase in temperatures by 2.5°C would reduce net revenues by US$079 billion and 5°C by US$1.94 billion. His study therefore indicated that climate change was not good for the economy of Cameroon.

Seo and Mendelsonh (2008) analysed impacts of climate change on animal husbandry and the way in which farmers adapted in 10 African countries. The study also used the Ricardian method to assess possible impacts on climate change on large and small farms. The results indicated that warming resulted in increased incomes for small farms and decreased incomes for large farms.

Small farms were discovered to have a more temperature elasticity than large farms as they were able to shift from crops to livestock due to increases in temperatures. Large farms were found to be less responsive to increase in temperatures because farmers specialised in livestock and could not use crops as substitutes. The results also indicated that precipitation decreased net revenues per farm for both small and large farms. For large farms, precipitation dropped net revenues more than for small farms. Again, small farms were more responsive to precipitation as they were able to shift from livestock to crops.

A similar study conducted by Galvin *et al.* (2001) in Tanzania to assess vulnerability of farmers to climate variability, used a pastoralist socio-economic model linked to the ecosystem model to investigate drought scenarios and wet season scenarios of changes that could impact pastoralists and their ecosystems. The results of drought scenarios indicated a decline in livestock numbers and milk yields due to disease incidences. The results of the wet season scenario indicated very small impacts on households because households in the study area were not well connected to the market. According to Mubaya *et al.* (2010), in Zambia and Zimbabwe, the impacts of drought were shortage of water for livestock that compromised the quality of pastures. This in turn resulted in reduced amount of draught power that could be provided by livestock. To make matters worse, farmers could not afford to hire labour in order to supplement the little draught power that was available. Drought also resulted in livestock diseases and deaths.

Mubaya *et al.* (2010) also revealed negative socio-economic impacts of drought in Zimbabwe and Zambia which were shortage of income from livestock cultivation. As a result, they could not afford to send children to school. Farmers also experienced theft of livestock and that reduced the number of stock. The reduction in the number of stock resulted in the selling of stock by households in order to meet household daily obligations that required cash. The excessive rains that were experienced in Zimbabwe and Zambia had both negative and positive impacts. Livestock health deteriorated and they died as most farmers could not afford veterinary costs. Excessive rains also caused collapse of bridges and damage of roads. Farmers had to walk long distances to get transport to the city. There were also other setbacks that were reported such as destroyed houses, schools, infrastructure, and people being swept away by rivers. The positive impacts of excessive rains were adequate pastures for livestock in both countries. In Zambia's

Monze district, farmers received good yields for cowpeas and sweet potatoes because they lived on high ground. The yields in turn increased household incomes.

In South Africa, research by Gbetibouo (2006) using household survey in the Limpopo River Basin of South Africa for the farming season 2004–2005, examined how farmers' perceptions corresponded with climate change recorded data. The results of the study revealed that rainfall was characterised by large inter-annual variability, with the previous three years being very dry. Again, the analysis showed that farmers' perceptions of climate change were in line with the climatic data records (Gbetibouo, 2006). It was found out that approximately half of the farmers studied had adjusted their farming practices to alleviate climate change effects. The only inhibiting element to adaptation was lack of access to credit as cited by farmers. The conclusion from the study was that household size, farming experience, wealth, access to credit and water, tenure rights, off-farm activities, and access to extension were the main factors that enabled farmers to adapt to climate change. It was therefore recommended that the government should design policies aimed at improving these factors (Gbetibouo, 2006).

Climate change has been found to have serious environmental, economic, and social impacts in South Africa. Most rural farmers depend on natural resources, agriculture and especially livestock production for their livelihoods. Climate change has been seen as a threat to agricultural productivity which is mostly rain-fed. In dealing with climate change the South African government established a National Climate Change Committee (NCCC) with the purpose of helping in developing a climate change policy. The NCCC was set up in 1994 to advise the then Minister of Environmental Affairs and Tourism on matters related to national responsibilities towards climate change under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. The government also established a Government Committee on Climate Change (GCCC) to facilitate co-ordination across various government ministries and departments. This committee was meant to advise the directorate of Climate Change and Ozone Layer Protection on matters relating to national responsibilities with respect to climate change, the UNFCCC and the Kyoto Protocol.

2.3 Impact of climate change on the livestock sector

In pastoral and agro-pastoral systems, livestock are key assets for the poor, providing a cushion against shocks of multiple economic, social, and risk management functions. Throughout the Greater Horn of Africa (GHA) made of Sudan, Eritria, Somalia, Djibouti, Ethiopia, Uganda, Rwanda, Tanzania and Burundi, livestock production is vital for household economies. Livestock are kept for various reasons such as income, manure, ploughing, status and savings (Notenbaert *et al.,* 2010). The impact that climate change will bring about is expected to increase the vulnerability of livestock systems and to reinforce existing factors that are simultaneously affecting livestock production systems such as rapid population and economic growth, increased demand for food (including livestock) and products (FAO, 2007).

The livestock sector is predicted by a number of studies to be affected adversely by climate change. Studies predict that for livestock, there will be greater induced heat stress and water demand will become vital to the location of livestock systems. In the central United States of America during the years 1992, 1995, 1997, 1999, 2005, and 2006, some feedlots for intensive cattle feeding operations lost in excess of 100 head each during severe heat episodes. The heat waves of 1995 and 1999 were particularly severe with documented cattle losses in individual states approaching 5,000 head each year (Notenbaert *et al.,* 2010). The intensity and/or duration of the 2005 and 2006 heat waves were just as severe as the 1995 and 1999 heat waves.

Livestock production is of high importance not only in South Africa but globally. According to Blummel *et al.,* (2010), livestock contributes 40 percent to agricultural GDP and employs more than a billion people. It also creates livelihoods for more than 1 billion poor people. Research also shows that livestock production is the world's dominant land use, covering about 45 per cent of the earth's land surface, much of it in harsh and variable environments that are unsuitable for other uses. It is believed that climate change can impact the amount and quality of produce, reliability of production and the natural resource base on which agriculture depends. From the nutritional point of view, livestock contributes about 30 percent of protein in human diets globally and more than 50 percent in developed countries. In many developing countries, livestock has been considered to be the backbone of agriculture as it has provided draught power and farmyard manure before the promotion of modern agriculture in the middle of the 20^{th} century.

In developing countries, livestock production efficiency for small-scale farmers and pastoralists is limited by factors such as shortage of livestock feeds, poor health for both human and livestock, poor access to markets, unresponsive policy environments, and degradation of natural resources. Among those most readily available to the world's poor are farm animals. One-third of the world's 6 billion people depend on farm animals. Of the 1.3 billion people living in absolute poverty, 80 percent live in rural areas and out of these, 678 million poor keep livestock (Amboga and Rowlinson, 2008). The livestock products perform a lot of functions that are advantageous to the health and welfare of households such as provision of cash income from sales of animal products, nutrition from consumption of livestock products, fertilization of soil with the manure and draught power during planting times as most of the poor households do not own tractors. It is also cost-effective to keep livestock because they feed on grass and shrubs which grow on their own in the fields and along roadsides instead of grain. After harvest time, they are allowed to feed on maize stalks and cabbage leftover leaves which could have otherwise been a waste or made compost in many cases.

In the rural tropical developing countries where many poor people reside, most farm animals are livestock. Examples of livestock kept are cattle, buffalo, sheep, goats, pigs and poultry. These livestock are their most important assets. Livestock is liquid cash in cases where cash is needed and thus generates income for the poor. The income sustains livelihoods and the increasing demand for animal products such as milk and meat makes it imperative to rear livestock in these areas. Climate change is becoming a major challenge in these areas. Similarly, in the Eastern Cape province (the study area), livestock farming is still the backbone of rural household economies. Livestock still provides manure for crop production and draught power. As in other rural communities in South Africa, livestock is regarded as a store of wealth and is also associated with status. Ainslie (2002) indicated that livestock in the Eastern Cape is kept as a store of wealth for reasons such as provision of immediate cash, milk, draught power, manure and less frequently meat. The loss of livestock might lead to chronic poverty with long-term effects in rural communities. Among the direct effects of climate change, there will be higher temperatures and changes in rainfall patterns, translating in an increased spread of existing vector-borne diseases and macro parasites of animals as well as the emergence and spread of new diseases.

According to Garforth (2008), poor livestock keepers are among those whose livelihoods are most vulnerable to climate change. Seemingly, extensive grazing systems become less viable in semi-arid areas that become even more warm and dry. As pests and diseases move into new areas, the poor are more likely to experience increased morbidity and mortality among their animals. The poor are the first to suffer market impacts of climate change on the cost of inputs. In low lying coastal areas, poor livestock keepers facing loss of land due to rise in sea-levels, will experience difficulty to find alternative sites on which to re-establish their livelihoods. On the other hand, climate change is likely to lead to new market opportunities for livestock. Changes in levels and variability of physical, environmental parameters such as precipitation and temperature are only one part of the context within which households create their livelihoods; there are many other sets of factors that influence their options, the choices they make, and the outcomes they achieve. These include institutions that affect the accessibility and security of the resources at their disposal: institutions such as land tenure arrangements, financial services, knowledge and information services, local and central government systems. The market environment, for both inputs and produce, helps to determine the viability of livelihood options in the short and long term; while the social context affects the social capital to which the individual and household can look for support in times of hardship, uncertainty and change.

Hoffmann (2008) forecasted direct and indirect impacts of climate change on livestock production and diversity. The direct impacts were catastrophic events such as droughts and floods, or disease epidemics related to climate change. Local and rare breeds were at risk of being lost in localized disasters. To guard against such disasters, it was necessary to keep spatial information of breeds and valuable breeding stocks such as conservation of genetic material, or other measures to ensure genetic recovery in the case of a disaster.

Hoffmann (2008), also forecasted that portfolio of breeds demanded by society would change, and that depends upon the ecosystem changes brought about by climate change and other pressures and the trade-offs among the public goods considered. Developed and developing countries differ in their adaptation capacity and the expected interactions between climate change adaptation and mitigation. Developing countries that have a low adaptation capacity will have to apply a closer relationship between climate change adaptation and development policy. They also have weak capacity for high-tech breeding programmes to increase their breeds' adaptation.

According to Nassif (2008), livestock production in Morocco is an integral component of agriculture. Based on the agricultural census of 1996, livestock keeping is practiced by 1 100 123 farm-households which represents three fourths of the approximately one million and half (1 496 349) farm-households of Morocco. Livestock provides employment to 20 percent of the active population. It contributes 36 percent of agricultural add –value, and satisfies up to 87 percent of the national demand for dairy products, 98 percent for red meat and 100 percent for poultry meat. In pastoral and agro-pastoral systems of the country, livestock is central to livelihoods of rural communities. It constitutes the most important, if it is not the main source of income. Most importantly, livestock production is carried out in arid and semi arid regions of the country. This means the high degree of exposure of livestock to climatic variability and erratic nature. Nassif (2008) believes that in Morocco, variations of animal stock were well correlated to climatic conditions. Climate change increases the vulnerability of the livestock as the severe droughts were experienced in Morocco. FAO (2006) highlighted projections suggesting that globally, continued economic growth will push up average incomes faster than any likely price increases, demand for animal protein as a share of total food consumption was projected to continue to increase and the share of food in average household expenditure will continue to decline.

The indirect impact of climate change on livestock production and diversity were changes in the ecosystem. Ecosystem changes resulting from climate change were seen relevant for livestock production because of the land dependency of most production systems and the close interaction of livestock genetic resources with other agricultural biodiversity. Water, feed and forage were the most important inputs for livestock production. Their overall and relative availability may be affected by the ecosystem changes, which were accelerated by climate change. Impacts of direct human pressures such as non-sustainable practices, infrastructure development and fragmentation on rangeland ecosystems currently seem to be greater than those directly attributable to climate change (Easterling and Apps, 2005).

Another indirect impact of climate change on livestock production and diversity was the changing host-pathogen interactions and disease challenge. According to Epstein (2001), the expected increase and often novel disease pressure related to climate change was expected to favour genotypes that were resistant or tolerant. FAO (2006) listed breeds, mainly from developing countries, that were reported to withstand tick burden, tick-borne diseases, internal parasites or foot-rot.

Changing terms-of-trade of livestock production inputs compared to other products was another indirect impact of climate change. Long-term breed survival depended on the comparative advantage of a breed to provide the desired goods and services in a given environment. Non-food sector demand for feed inputs was expected to increase, thereby potentially worsen the negative effects of climate change-induced reduction in feed supply. Predicted shift of C_3 to C_4 grasslands and increase in shrub cover in grasslands would tend to reduce forage quality (Christensen *et al*., 2004). Livestock could compensate for shrub encroachment to a certain extent if the animals were able to select high quality diets from different plant components or species.

Climate change can have an effect on land use and land use systems. As temperature increases and rainfall increases or decreases and becomes more variable, the niches for different crops and grassland species change. As temperate areas become warmer, substitution for crop species more suited for warmer climates can occur. In parts of Africa, reductions in the length of growing period are likely to lead to maize being substituted by crop species more suited to drier environments such as sorghum and millet (Thornton *et al*., 2009). In marginal arid places of Southern Africa where crops grow, the reductions in length of growing period and the increased rainfall variability is driving systems to a conversion from a mixed crop-livestock system to a rangeland-based system, as farmers find growing crops too risky in those marginal environments. These land-use changes can lead to a different composition in animal diets and to a change in the ability of smallholders to manage feed deficits in the dry season. These two effects can have negative effects on animal productivity and on the maintenance of livestock assets.

Climate change can also change primary productivity of forages and pastures. However, the effects are significantly different depending on location, production system and on crop and pasture species. In C_4 species, increases in temperature up to 30-35 °C will in general increase the productivity of fodders and pastures, as long as the ratio of evaporation to potential evapo-transpiration and nutrient availability do not significantly limit plant growth. These effects are mediated primarily through increases in the maximum rates of photosynthesis and rates of leaf appearance and extension, which lead to higher leaf area indexes and therefore, higher rates of net assimilation (Johnson and Thornley, 1985). For feed crops, the end result for livestock production is a change in the quantity of grains and availability of metabolisable energy for dry season feeding.

Climate change effects are also expected in rangelands. In the semi-arid rangelands of the Sahel, for example, where the ratio of actual to potential evapo-transpiration limits plant growth, rangeland productivity is likely to decrease. Such changes could have enormous impacts on the livelihoods of pastoralists dependent on these rangelands through the numbers of animals that they can keep, livestock productivity, and potential loss of animals during the dry season, and longer routes in search of feed for animals.

Climate change can also change species composition in rangelands and some managed grasslands and yet species composition is an important determinant of livestock productivity (FAO, 2010b). As temperature and carbon dioxide levels change due to climate change, the optimal growth ranges for different species also change resulting in changes in species composition and their competition dynamics. Small changes in temperature alter this balance significantly and often result in changes in livestock productivity; an implication of this is that significant changes in management of the grazing system may be required to attain the production levels desired. It has also been suggested recently that the proportion of browse in rangelands will increase in the future as a result of increased growth and competition of browse species due to increased CO_2 levels. This will have significant impacts on the types of animal species that could graze on these rangelands and may alter the dietary patterns of the communities' dependent on them.

Increase in temperatures induces heat stress on livestock. A study conducted by Sunil *et al.* (2011) in tropical livestock revealed that increased temperatures affected health and performance together with productive capacity of livestock. Heat stress lowered feed intake of animals which in turn reduced their productivity in terms of milk yield, body weight and reproductive performance. Heat stress also reduced libido, fertility and embryonic survival in animals. Primary effect of environmental stress in neonates was increased disease incidence associated with reduced immunoglobulin content in plasma. Heat stress in late gestation reduced foetal growth and altered endocrine status of the lamb.

Carryover effects of heat stress during late gestation on postpartum lactation and reproduction were also detectable (Collier *et al.,* 1982). Heat stress resulted in reduced birth weights of calves (Sinul *et al*., 2011). Heat stress in lactating animals resulted in dramatic reduction in roughage intake, gut motility and rumination, which in turn contributed to decreased volatile fatty acid. In such cases, rumen pH also declined (Collier *et al.,* 1982). Hahn (1995) reported that conception rates in dairy cows were reduced by 4.6 percent for each unit change. Amundson *et al.* (2005) reported a decrease in pregnancy rates of Bos taurus cattle by 3.2 percent. These data were obtained from beef cows in a range or pasture management system. Amundson *et al*. (2005) also reported that of the environmental variables studied, minimum temperature had the greatest influence on the percentage of cows getting pregnant. Clearly, increases in temperature and/or humidity had the potential to affect conception rates of domestic animals not adapted to such conditions.

Climate change can also change the quality of plant material. According to Minson (1990), increased temperatures increased lignifications of plant tissues and reduced the digestibility and the rates of degradation of plant species. This led to reduced nutrient availability for animals and ultimately to a reduction in livestock production, which could have impacts on food security and incomes through reductions in the production of milk and meat for smallholders.

The potential complexity of climate change influences, with other factors associated with vector populations is well illustrated by the distribution of tsetse flies in sub-Saharan Africa (McDermott *et al*., 2002). Tsetse flies transmit African trypanosomes widely in livestock (ruminants, equines, and pigs). Tsetse flies are very sensitive to environmental change, either due to climate or direct human impacts on habitat. Predictions of climate and population change on tsetse flies density indicates that tsetse flies populations and animal trypanosomosis will decrease the most in semi-arid and sub-humid zones of west Africa and in many but not all areas of Ethiopia, Eastern and Southern Africa through a combination of population pressure on savannah species and climate change pressure on riverine species. The animal trypanosomosis situation in the humid forest zones of central and western Africa is expected to be less changed. Sleeping sickness, particularly the gambiense type, is predicted to continue to be a major problem, if concerted control efforts are not implemented (FAO, 2010b).

According to Salem and Smith (2011), drought is certainly one of the most important natural threats for water availability and quality, affecting production of rangelands and subsequently, livestock performance in the already difficult context of arid areas. In the low rainfall areas of much of Africa and Asia, small ruminants represent the principal economic output, contributing a large share of the income of farmers. The animal numbers are reported to have increased over the last two decades, driven by a rising demand for animal products and, in some countries, subsidized feed prices (e.g. barley, maize). Changing climatic patterns are increasing desertification, resulting in a decline in rangeland resources, which are often insufficient to meet current demand, coupled with a fall in total feed resources due to overgrazing. This is coupled with dry environments which result in nutrient shortages for livestock.

2.4 The contribution of livestock to climate change

Livestock is not only affected by climate change but is also perceived through research to be a potential contributor to climate change. According to IPCC (2007), agricultural livestock account directly for about 9 percent of total anthropogenic GHG emissions on a global scale. Throughout the livestock production lifecycle which includes burning fossil fuel to produce mineral fertilizers used in feed production, methane release from the breakdown of fertilizers and from animal manure, land-use changes for feed production and for grazing, land degradation, fossil fuel used during feed and animal production, fossil fuel used in production and transport of processed and refrigerated animal products, there is an estimated 18 percent of global anthropogenic emissions (Gill *et al.,* 2010). Livestock production and associated activities (including land-use change) are estimated to account for 18 percent of global anthropogenic emissions. Gill *et al*. (2010) also estimated methane emissions that accounted for 30 percent of these emissions, similar to the relative contribution of N_2O, while land use and land-use change, together with deforestation related to provision of grazing, accounted for 38 percent.

According to FAO report (2010a), the main sources of GHGs from animal agriculture were deforestation of the rainforests to grow feed for livestock and methane from manure waste. Methane was 72 times more potent as a global warming gas than CO_2. Raising of animals, slaughtering, processing, refrigeration and transport of meat around the world were other main sources of GHGs. FAO (2010a), using a methodology that considered the entire commodity chain, estimated that livestock were responsible for 18 percent of GHG emissions, a bigger share than that of transport. It accounted for 9 percent of anthropogenic carbon-dioxide emissions, most of it due to expansion of pastures and arable land for feed crops. Livestock emitted methane and other GHGs through excrement and belching.

The FAO report (2010a) estimated that cow manure and flatulence generated 30 to 40 percent of total methane emissions from human-influenced activities. Livestock generated even bigger shares of emissions of other gases with greater potential to warm the atmosphere as much as 37 percent of anthropogenic methane, mostly from enteric fermentation by ruminants, and 65 percent of anthropogenic nitrous oxide, mostly from manure. The report added that the livestock sector's potential contribution to solving environmental problems was equally large, and major improvements could be achieved at reasonable cost. The FAO report (2010a) also indicated that grazing occupied 26 percent of the earth's terrestrial surface which was due to expansion of grazing land through deforestation, especially in Latin America. Deforestation resulted in overgrazing, soil compaction and erosion attributable to livestock activity.

Livestock emissions were also confirmed by Moran (2008) as contributing to climate change. According to literature, livestock emissions are not the same. They depend on whether livestock is raised intensively or extensively. Livestock that is raised intensively through grain feeding, especially in industrialised countries, emit much higher levels of GHGs than livestock that is raised extensively and grass-fed. Extensive farming is quite common in developing countries.

Developing countries are characterised by small-scale farmers who feed their animals on grass and other common forage, with seasonal supplements of stalks and other harvested crop wastes. Another common practice in the developing countries is that herders periodically move their stock in search of greener pastures and water. There are very few alternatives for making a living beyond crop and livestock farming and both these activities leave an environmental footprint. Moran (2008) also asserted to the notion that in many developing countries, the poorest households have a high dependence on livestock production. There is a growing consensus that the biggest concern about livestock production in developing countries is not how much farm animals are emitting GHGs but to what extent a hotter and more extreme tropical environment will reduce livestock productivity. Reducing productivity by even a small amount will threaten supplies of livestock products such as milk, meat and eggs to hungry communities that need these nourishing foods the most.

Goodland and Anhang (2009) discovered that livestock and their by-products actually accounted for at least 32, 564 million tons of CO_2 per year, or 51 percent of annual worldwide GHG emissions, and had been unaccounted for in other researches. Goodland and Anhang (2009) also argued that the amount of carbon stored in livestock was trivial compared to the amount stored in forest cleared to create space for growing feed and grazing livestock. They argued that livestock (like automobiles) were a human invention and convenience, and a molecule of CO_2 exhaled by livestock was no more natural than one from an auto tailpipe. Moreover, while over time an equilibrium of CO_2 might exist between the amount respired by animals and the amount photosynthesized by plants, that equilibrium has never been static. Today, tens of billions more livestock are exhaling CO_2 than in preindustrial days, while earth's photosynthetic capacity to keep carbon out of the atmosphere by absorbing it in plant mass, has declined sharply as forest has been cleared. According to Clark *et al*. (2011), in New Zealand, enteric methane (CH_4) emissions arising from ruminant animals constituted 30 percent of total CO_2 emissions. Enteric CH_4 emissions had increased by 9 percent since 1990 and extensive research had been undertaken to develop reliable methods for measuring enteric CH_4 emissions.

Based on the most recent data, the increase in population and incomes worldwide, along with changing food preferences, were stimulating a rapid increase in demand for animal products such as meat, milk and eggs, while globalization was boosting trade in both inputs and outputs. In the process, the livestock sector was undergoing a complex process of technical and geographical change which resulted in a shift in production from the countryside to urban and peri-urban areas, and towards sources of animal feed, whether feed crop areas or transport and trade hubs where feed was distributed. There were also shifts in species, with accelerating growth in production of pigs and poultry (mostly in industrial units) and a decline in that of cattle, sheep and goats, which were often raised extensively. Today, an estimated 80 percent of growth in the livestock sector comes from industrial production systems. Due to these shifts, livestock were entering into direct competition for scarce land, water and other natural resources (FAO, 2010b).

According to FAO (2010b), the two major sources of agricultural methane emissions are enteric fermentation in livestock and livestock manures. The rapid breakdown of herbage proteins in the rumen and inefficient incorporation of herbage nitrogen by the rumen microbial population are major causes of nitrogen loss and gaseous emissions. Scarcity of readily available energy during the time of maximal protein degradation restricts microbial protein synthesis. Ammonia accumulates as a waste product and is absorbed from the rumen and excreted as waste nitrogen in urine. According to McMichael *et al.* (2007), methane and nitrous oxide are more important emissions from animal husbandry than is carbon dioxide. In addition to that, methane is a potent GHG whose full contribution to climate change has recently been re-assessed as being more than half that of carbon dioxide.

Hope, *et al.* (2001) discovered that ruminants contributed a significant amount of methane as well as a significant amount of nitrous oxide to the total GHG emissions for the United States, due to manure management and fertilizer application. Garnett (2009) also discovered that livestock contributed significantly to global GHG emissions and, at a time when the world urgently needs to achieve deep emission cuts, consumption of livestock products and production is set to grow due to global population that is projected to increase to 9 billion by 2050. These GHG emissions from animal husbandry are estimated to exceed those from power generation and transport and as a result, they bring a threat of climate change to the MDGs worldwide. Therefore, these emissions need to be considered as a significant threat that can delay progress towards achieving MDGs.

According to FAO (2010a), the livestock sector is usually driven by diverse policy objectives, and decision-makers find it difficult to address economic, social, health and environmental issues at the same time. The fact that so many people depend on livestock for their livelihoods limits the policy options available and leads to difficult and politically sensitive trade-offs (FAO, 2010a).

2.5 Impact of livestock production on the environment

Livestock production too, seems to contribute to environmental degradation. According to researchers from Stanford University, the United Nations Food and Agriculture Organisation (FAO) and other organisations, the harmful environmental effects of livestock production are becoming increasingly serious at all levels (locally, regionally, nationally and globally), and urgently need to be addressed. FAO (2010b) reported livestock production as one of the major causes of the world's most pressing environmental problems, which included global warming, land degradation, air and water pollution, and loss of biodiversity. As demand for meat grew, the report explained, so did the need for pasture and cropland, making deforestation an additional concern. The report further explained that extensive grazing also took a toll on arable land. Researchers also saw an increasing consumption of meat and meat products around the world and it was growing at a record pace which was projected to double by 2050. As a result of this increasing pace, the study foresees tremendous environmental problems that will lead to land degradation, air and water pollution, as well as loss of biodiversity.

According to the FAO (2010b), when emissions from land-use were factored in, the livestock sector accounted for 9 percent of all carbon dioxide emissions derived from human-related activities, as well as 37 percent of methane emissions, primarily gas from the digestive system of cattle and other domesticated ruminants together with 65 percent of nitrous oxide gases, mostly from manure. It therefore became imperative that the problems surrounding livestock production be considered together with economic, social, health and environmental perspectives.

2.6 Challenges for poverty alleviation

Poor communities are traditionally known to be the most vulnerable to climate change. They are also traditionally known for their very limited and negligible contribution to climate change. However, a study conducted by Konyak (2010) in Konyak village of the Himalayas revealed that poor communities, irrespective of percentage contribution to climate change, contributed to climate change by their actions of destroying forests for lodging. Their mining also made a contribution to climate change. Their actions were out of illiteracy and ignorance. According to Konyak (2010), more than 50 percent of the villagers were illiterate during the time of the study. The subject climate change becomes a big challenge which takes a long time for the villagers to understand and act upon. This leaves us with a question as to how many years will it take for people living in villages to understand climate change and act upon because climate change is already perceived and experienced worldwide. Deforestation is also a problem in South Africa because of an increase in number of people who clear forests for residential purposes. This is a challenge to poverty alleviation which is one of the MDGs that have to be achieved by 2015.

The most significant trend in developing countries is the rapid growth in demand for livestock and livestock products driven by urbanisation, population growth and income increases. Studies show that the poor are able to play a greater role in some livestock production and market chains compared with others who are not poor. Smallholders are major players in the dairy sector indeed, almost all the meat and milk in Africa is produced in agro-pastoral systems (De Haan *et al*., 1997). On the other hand, industrial systems are the major actors in the rapidly growing poultry market. For these demand-led and changing livestock systems, the focus on research that can benefit the poor needs to attend to changes in the environment and their effects on livestock production. These changes will be influenced by both supply-side changes in natural resource use as well as market-led demand changes.

According to Steinfeld *et al*. (2006), at a global level, livestock products contribute 30 percent of the protein in human diets, while in industrialised nations, this rises to 53 percent. This figure is predicted to increase, with the global production of meat predicted to increase from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050, and milk from 580 tonnes to 1043 tonnes in the same period. In 2005/6, the mix of species contributing to global meat production was 24 percent from cattle, 31 percent from poultry, 39 percent from pigs and 5 percent from sheep and goats.

In developing countries, livestock systems are changing rapidly in response to a variety of factors. Globally, human population is expected to increase from around 6.5 billion today to 9.2 billion by 2050. 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 the tropics and sub-tropics. The potential impact of these global factors of change on livestock systems and the resource-poor people who depend on them is considerable.

According to Gill *et al.* (2010), the area of land used for grazing is more than twice that used for arable and permanent crops across the globe. While some grazed land can be ploughed up for crop production, such a change in land use has a net release of carbon to the atmosphere and in many parts of the world, is a high risk venture, due to unpredictable rainfall. It is difficult to see how it would be possible to feed an increasing human population without making use of this grazing land. The livestock sector accounts for 40 percent of agricultural GDP, employs 1.3 billion people and creates livelihoods for 1 billion of the world's poor (Steinfield *et al*., 2006). Because the poor are the most vulnerable to climate change, it is therefore imperative to make the poor understand the dangers of their unconscious contributions to climate change. It is also important to make them aware of the contribution that they make to the GDP of the country so that they can farm responsibly and take good care of the resources that they use to produce livestock.

2.7 Perceptions on climate change

In Europe, Asia and America, climate change has been perceived and action has been taken to mitigate its effects. The individuals that did not adapt in the countries studied, did not have the resources to do so. A study conducted by Battaglini *et al*. (2009) about European winegrowers' perceptions on climate change and options for adaptation, indicated that ongoing climate change over past decades was reported to have significantly high percentage of winegrowers adapting to climate change. Adaptation to climate change was evidenced by a change in perceived quality and quantity of the produce. Adaptation measures were irrigation and management of pests. The winegrowers that did not adapt lacked knowledge about correct varieties to plant, and others did not adapt simply out of being sceptic to do so.

In Asia, case studies were conducted by a thematic group of climate change in various regions of the Himalayas to investigate the peoples' perceptions about climate change. The first study was conducted by Tripathi (2010) in the Indo-Gangetic Region to investigate perceptions of the local people on climate change. The variables that were used in the study were temperatures, rainfall, agriculture, weeds and other livelihoods. The study revealed that the people in the Indo-Gangetic Region indeed perceived a significant change in temperature distribution and a definite reduction in the number of winter months, which then lasted for only two months. Almost 100 percent of the respondents perceived the changes in winter. These perceptions were not in line with traditional weather descriptions because temperatures were way above the normal temperatures. Rainfall patterns were perceived to be variable and declining from 1999 until 2008. The respondents observed that rains started later than normal and this was harmful for the maturing of crops. The respondents also observed a decrease in the number of cloudy days during the monsoon.

As for agriculture, the observation was that rice and wheat (major crops) production declined due to a reduction in fog and lesser cold over the years. Respondents also observed a reduction in the production of barley and oil crops such as mustard and linseed. This observation was similar to the observation of the people of Tangmang village in the Meghalaya state of the Himalayas, who also realised noticeable changes in temperature accompanied by erratic rainfall patterns resulting in reductions in crop yields (Lyngdoh and Baishya, 2010). Another observation was a significant shift in the sowing season of wheat between 1977 and 1995. Weeds that were controllable because of cold weather, were no longer controllable because the cold weather was no longer experienced due to increased temperatures. Shepherds and herdmen rearing sheep and goats noticed changes in wild varieties of fodder and loss in fruits that were relished by goats and sheep. They believed that the reduction in colds was responsible for such anomalies. They also reported that the preferred grass species was also lost and other grass species declined thereby creating scarcity of fodder.

Another study that was conducted by Patwal (2010) in the Himalaya village called Baunsari, used the variables: weather patterns, rising temperatures, water and forests and agriculture to study perceptions on climate change. The respondents indicated that they had perceived that rainfall had become relentless with a decline in the overall rainfall for the past 10 to 15 years. At first, they thought that it was an act of God, and as a result they performed sacred rituals in order to normalise the weather patterns. Older women thought it was caused by increasing sins committed by the people. People even stopped worshipping traditional gods and goddesses which were mainly related to the natural resources around them. At a later stage, they understood that the problem was caused by changes in climatic patterns. Respondents also observed a snowfall that occurred 10 years after the regular annual feature and also less winter rainfalls, the rainfall cycle shifted by 2 to 3 months.

According to Patwal (2010), due to rising temperatures, some fruits in the Himalayas could not survive the extreme temperatures and other fruits such as mangoes, found the temperatures conducive to growth. Respondents also observed an increase in termites that destroyed construction wood and causing the dilapidation of houses. Mosquitoes were also prevalent but respondents did not link the prevalence to climate change, but to the construction of ablutions. Water sources had dried up resulting in reduction in irrigation water for land and reduction in crop and forage production. The people of Baunsari observed a significant decrease in major crops such as wheat, barley, pulses, and soybeans. The decrease in crop production was exacerbated by new diseases that destroyed crops. There was also an outbreak of insects that destroyed the crops. However, there were positive effects that were experienced by the people of the region. Ripening period for crops, especially wheat was shortened by 15 to 20 days.

A similar study that was conducted by Sharma (2010), about perceptions on climate change in the Himachal Pradesh district of the Himalaya, raised questions around awareness about climate change, perceptions on the effect of climate change, overall perception on the effect of climate change and effects of climate change on other agricultural related aspects. The findings revealed that two-thirds of the respondents were aware of climate change. A significant majority had knowledge about various types of changes in the climate such as increasing pollution, melting glaciers, cyclones incidents, increased crop failure and rise in sea-level. A majority of respondents perceived a decrease in food grain production, decrease in the quality of fruit, frequency of rainfall and soil erosion, which resulted in adverse effects in the production of fruits. The overall perception of respondents about impacts of climate change, as revealed by the data, was that 36 percent perceived effects of a change in climate. Fourty percent was neutral i.e. they did not see that climate change had effects on them. Fifty four percent changed their cropping patterns and the outstanding reasons for the change were the inadequate chilling hours required, especially for fruits. Concerning agriculture, the respondents perceived that the use of fertilizer and pesticides had increased due to climate change. This was definitely increasing household expenditures on farming activities.

Arya (2010) also conducted a study about perceptions on climate change in village communities of Garhwal Himalaya. The study revealed different perceptions on climate change. The respondents perceived unseasonable rainfall, decreasing moisture and increasing heat. They also observed drought, low crop production, snowfall and fluctuations in temperatures. Increased soil erosion due to heavy rainfall in the rainy season, and decreased water level due to high temperatures were other observations. The villagers had different perceptions about the reasons for climate change. Among the reasons for the change in climate, they pointed increasing human population, forest fires, increase in the use of plastic bags and other non-degradable materials. They also pointed out increased use of motor vehicles and chemical fertilizers, and the disturbance in the ozone layer caused by harmful gases like carbon dioxide and other chemical gases. These perceptions about causes of climate change indicated that the villagers were not ignorant about climate change. At least they were aware of the existence of climate change and contributing factors to it. Adaptation or mitigation was not something far from being planned and implemented. As a result, the villagers suggested measures such as introducing climate change subjects to schools and colleges, government banning the use of plastics, social and public awareness campaigns, control of bush fires, more plantations around water sources and clear forest and management policy.

Rawat (2010) conducted a study on awareness about environmental issues and perceptions on climate change in Garhwal Himalaya region, Kunjapuri hills. The study revealed mixed responses on awareness about environmental issues. About 50 percent were confused about environmental issues but they perceived a change in climate and increased temperatures. In addition, a majority perceived changes in temperature, erratic precipitation, and depletion of natural resources which had been taking place for the past 3 to 4 years. Almost 100 percent of the respondents agreed to the change in the cropping patterns and animal keeping for the past 4 to 5 years. The unfortunate part about the respondents in the village was that they could not afford to adapt to climate change because they had little resources and expertise to adapt. Although they had an understanding of climate change, there was little that they could do to mitigate the effects of climate change or to adapt to climate change.

Under the same umbrella of case studies conducted in the Himalayas, a study was conducted by Rai and Chakesang (2010) about perceptions on the effects of climate change on traditional livelihoods practices in the Eastern Himalayas of India. The study focused on the two traditional agricultural systems which were rice-based fish farming and slash-and-burn farming systems which had always been controversial. The study discovered that the communities observed that rice based-fish farming had become more vulnerable to diseases in an alarming manner and the communities were becoming helpless. The study also discovered that the slash-and-burn farming system was imposing carbon in the environment.

What has been common in all these studies in the Himalayas is that villagers perceived a change in climate. The indicators of a change in climate, according to their observations, were increased temperatures and erratic rainfall patterns. The observed results were reduction in crop and fodder yields, and increased prevalence of diseases and pests. Climate change has been perceived with different interpretations. Some villagers who were ignorant about climate change thought the incidences were an act of God who was angry with the sinful acts of the villagers. Other villagers in the areas of study were not ignorant about climate change. The only problem was the means to mitigate the effects of climate change that were not available.

A similar study conducted by Bhushal (2009) in Nepal, revealed that 92 percent perceived long-term changes in temperatures of which 90 percent saw an increase in temperatures. The increase in temperatures was in line with statistical record of temperature data for the period between 1978 and 2007, which showed increasing trends, especially in winter. Although they observed irregular climatic conditions such as malfunctioning of the ecosystem and biological system, they were not aware of climate change. They had indigenous coping strategies as they managed forests well and diversified crops to limit risk. Although local people of Nepal had coping strategies, knowledge and awareness of climate change was a major challenge. The findings of this study agree with the findings of the study that was conducted by Rai and Chakesang (2010), who also conducted a study in Nepal. Climate change was viewed in terms of increased warming throughout the year, reduced regular snowfalls, hail and rainfall when snow was expected, and irregular water-flow in the small rivers. There was also an observed decline in cattle numbers due to dryness of pastures. Cattle were also observed to be suffering from diseases which were never seen before. As adaptation measures, farmers sold their cattle in order to avoid the risk of unexpected and untimely deaths. Other observations were unexpected flooding that caused damage to infrastructure.

A similar study conducted by Semenza *et al*. (2008) in the United States of America (USA) on public perceptions of climate change, also indicated that a vast majority (92 percent) was aware of climate change. Those that were aware also indicated willingness to adapt to climate change through different practices such as reduced gasoline consumption, decreased energy usage at home and also recycling. Barriers to adaptation were not knowing how to change behaviour in order to adapt, not having enough money, pessimistic behavioural patterns as well as not having enough time to change behaviour.

Another study conducted by Brondizio and Moran (2008) in the Amazon, revealed a different facet about perceptions on climate change. The study focussed on processes that mediated perceptions of climate change and behavioural responses at individual and local level. The study revealed that most farmers did not remember extended drought periods and the 1997/1998 El Nino-Southern Oscillations (ENSO). As a result, 40 percent of them did not change their land use behaviours in the face of the strongest 1997/1998 ENSO. Lack of extension services for adoption of new agricultural techniques, and climate information relevant to local level land-use decision, explained why good land-use behaviour was missing. Although farmers paid attention to climate information provided by the media, as cited by over 40 percent of farmers surveyed, the scale of information did not motivate changes in local farming behaviour. Less than 5 percent of farmers surveyed reported to have received information about the 1997/1998 ENSO event. They relied on personal experiences and good neighbourhoods to get information. Farmers highlighted poor infrastructure (e.g. roads/transportation cited as top concern of farmers) and limited access to credit and technology as their main problems. For the two surveyed areas, the proportion of farmers depending on manual labour and simple tools exceeded 95 percent with only 18 percent reporting some access to tractors, for instance, to construct ponds and/or open firebreaks. Limited access to credit and technology also contributed to bad land-use behaviour. Only 18 percent in the area of study owned tractors and only 5 percent reported to have received information about 1997/1998 ENSO event. The only practice they adopted was information sharing among themselves and to agree on when and where to burn the veld, delay planting times and add firebreaks as a way of adapting to climate change. Although 75 percent relied on personal experience, at least 85 percent took action to prevent accidental fires.

According to Moran *et al.* (2006), farmers used local methods such as animal behaviour, plant penology, testing salt humidity and sharing information to perceive changes in climate. Local weather experts are also recognised, and often cited as reliable, in interpreting environmental signals as indicators of weather and what to expect in seasonal climate patterns. As a whole, the proportion of farmers relying on the media, non-governmental organisations (NGOs), government offices, extension services and community groups to assess climate information for land-use decision, tended to be less than 10 percent in both study areas (Moran *et al.,* 2006).

Spence *et al*. (2010) in Britain discovered that a majority (78 percent) of respondents perceived a change in climate. The respondents believed that it was their responsibility to do something about climate change. Most of the respondents (68 percent) saw it important that taxpayers' money be used on British projects designed to tackle climate change. Adaptation to climate change in this study was everyone's concern as they took it to be their responsibility to personally help make a difference.

In African countries, climate change has also been perceived by many smallholder crops and livestock farmers. A study conducted by Mubaya *et al.* (2010), in Zambia and Zimbabwe, indicated that 80 percent of famers perceived a change in climate as they had noticed droughts and excessive rains in the past five years, which had both positive and negative impacts on farming. In the rural Sahel, local communities had a very clear memory of the years that were dominated by extreme climatic conditions and other significant events that affected production negatively. Households also perceived an increase in temperatures throughout the year with cold periods being shorter than warm and hot periods. Winds were also perceived to be stronger especially in dry seasons. Households perceived reduced rainfall as a major challenge to their farming whereas others perceived excessive rainfall. Wind was also mentioned as another problem in the area of study (Mertz *et al*., 2009). The same applies to the study by Osbahr *et al.* (2011) in Uganda, where farmers perceived the regional climate to have changed in the past 20 years. Farmers also felt that temperatures had increased and seasonality and variability had changed. Farmers reported detailed accounts of climate characteristics during specific years, with droughts in the late 1990s and early 2000s, confirming local perceptions that there was a shift in climate towards more variable conditions that were less favourable to production.

2.8 Adaptation measures

Some studies have focused on adaptation measures to tackle climate change. In most studies, the primary purpose for adaptation measures was to save the economies of the countries affected by climate change, and also recommend strategies to deal with the effects of climate change. Adaptation to climate change can be referred to as adjustment in natural and human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities (IPCC, 2001; Deressa *et al*., 2008). Studies indicate that livestock are more resistant and can adapt better to climate change than crops because of their mobility (Mannion, 1997; Meyer, 1996; Nisbet, 1991; Wackernagel, and Rees, 1996). They can be moved to pastures that are more productive during the shortage of feed. Livestock production systems can be diversified or breeds can be changed into those breeds that can withstand climate change conditions.

According to Smit and Wandel (2006), the concept of adaptation is rather new for the research community and has its origins in natural science. Adaptation is used for a longer history in ecology, natural hazards and risk management fields (Smit *et al.*, 1996). According to Phuong (2011), adaptation refers to the process of adapting and the condition of being adapted. Smit *et al.* (1996) also described adaptation as referring to any adjustment, whether passive, reactive or anticipatory, that can respond to anticipated or actual consequence associated with climate change. Smit *et al*. (1996) stated that adaptation involved adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events, together with longer-term climate change. IPCC (2001) mentioned adaptation as adjustments or interventions, which take place in order to manage the losses or take advantages of the opportunities presented by a changing climate. Adjustments or interventions in this concept include natural and human systems adjustments or interventions of government organisations, non-governmental organizations, private sectors, public sectors and policies. According to IPCC (2007), adaptation means the adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploits beneficial opportunities. Adaptation in a narrow sense refers only to those measures that are taken at the farm level.

Literature provides various types and explanations of adaptation to climate change. Literature provides reactive adaptation, anticipatory, autonomous and planned adaptation. Reactive adaptation means institutions, individuals, plants and animal actions, which are implemented after the fact, whereas anticipatory adaptation are decisions that are carefully discussed to be taken in advance for reducing potential effects of climate change before fact (Phuong, 2011). Adaptation to climate change is continuous and therefore it is hard to distinguish between actions which are carried out after and actions which are carried out before. Anticipation requires foresight and planning while reaction does not. However, in reality, anticipation and reaction are mixed and people often combine both reactive and anticipative adaptation strategies to cope with and adapt to climate extremes and climate variability. Smith *et al.* (1996) defined autonomous adaptation as natural or spontaneous adjustments in the face of climate change and planned adaptation as an intervention of human activities and actions that have been planned beforehand.

FAO (2009) considered climate change adaptation as spontaneous or organised processes whereby human beings and society adjust to changes in climate, by making changes in the operation of land and natural resource used systems and other forms of social and economic organisation in order to reduce vulnerability to changing climatic conditions. This definition is opposed to climate change mitigation. Climate change mitigation refers to organised processes whereby society seeks to reduce the pace and scale of climate change by reducing emissions of carbon and other GHGs, and increasing the sequestration of atmospheric carbon through absorption by vegetation or other forms of carbon sinks (FAO, 2009).

Adaptation to climate change is usually done by those communities or areas that have the capacity and resources to adapt (Brooks *et al*., 2005; Smit and Wandel, 2006). The vulnerable communities are referred to as vulnerable because they do not have the capacity to adapt to climate change. This brings us to the definition of adaptive capacity. Again, there is a lot of literature that provides various definitions of adaptive capacity. The IPCC (2001) defines adaptive capacity as an ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantages of opportunities or to cope with the consequences. According to Brooks and Adger (2005), adaptive capacity is the property of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability, or future climate conditions.

Some attempts have been made to determine how farmers and local communities have adapted to climate change. Zvigadza *et al.* (2010) in Zimbabwe identified traditional coping strategies in order to mitigate the effects of climate change. Community members sold small stalk such as goats, and sold forest products and firewood, in order to make up for lost incomes. They also diversified their farming practices, recycled water, practised traditional and Christian ceremonies to ask for rain, and used indigenous knowledge systems to prepare for future weather. Migration to South Africa was also a common practice. According to Mertz *et al.* (2009), adaptation strategies in the Sahel were to keep animals in stables, replacing draft horses with cattle which were more affordable to feed.

Oseni and Bebe (2010) evaluated adaptive traits and the ways in which animals survived in the dry lands of Kenya. The intention of the survey was to generate inferences that would provide strong basis for the design of breeding strategies for climate change adaptation in extensive livestock production systems of the arid lands. The results revealed that camels and cattle were drought tolerant livestock compared to sheep and goats. Camels showed the highest adaptability to heat stress and drought. However, all the animals (camels, cattle, sheep and goats) showed varying degrees of vulnerability to diseases associated with climate change. Goats and camels showed more vulnerability to diseases. To floods, cattle were adaptive compared to other animals because they could float in water channels. To feed shortages induced by climate variability, camels and goats were adaptive whereas sheep and cattle were more vulnerable. Lastly, for water source decline, camels were the only animals that could adapt. Cattle, sheep and goats could not adapt. Herders had traits that they preferred for animals to cope with climate change. They were animals with lower fodder requirements, high kid survival rate, maternal traits, body condition and animal morphology. They perceived that these traits were suitable for conformation to harsh climate variability.

According to Rihawi *et al.* (2007), in Syria adaptation measures were followed. They were matching breed and production environment, replacing high cost concentrates in the diets, adding value to products, increasing food hygiene, improving animal health, and also improving contribution of feeds from rangelands. In matching breed and production environment, they chose sheep and goat breeds that had important adaptive traits to dryland conditions. The Awassi, a coarse wool fat-tailed sheep, was very closely associated with the barley production cycle. Thus, it was well adapted to the high temperatures during stubble field-grazing in summer which coincided with the mating period. It was also adapted to variable feed quantity and quality supplied by grazing the steppe rangelands in spring and stubble field in summer. In replacing high cost concentrates in the diets, most fattening and milk producing systems used concentrates for critical periods based on grains, cotton seed cake and wheat bran. In view of expected rising prices and decreasing availability of grains in response to climate change, but also due to the increased use of cropland for bio-fuel production, alternative feeding options were of high importance for livestock producers. International Center for Agricultural Research in the Dry Areas (ICARDA) researchers tested and developed multi-nutrient feed blocks from nonconventional and cheap agro-industrial by-products, for supplementation in dry areas. Thus, multi-nutrient feed blocks with molasses and urea for lamb and milk production and for fattening were tested more intensively with the aim to replace barley in the diets. In some cases, the feed blocks were combined with urea treated straw. Urea-molasses feed blocks were tested on farm for strategic supplementation of ewes during critical periods in the production cycle, such as early mating, late pregnancy and lactation (Rihawi *et al.*, 2007).

Another adaptation measure was early weaning through creep feeding of lambs and this was an interesting option to increase the milk off-take and lamb weights at weaning. In an on-station experiment, raising twenty lambs by their mothers with access to supplemental creep feeding was compared to raising twenty lambs only by their mothers (control). Creep-feeding (25 percent crushed barley, 25 percent wheat bran, 25 percent crushed soybeans and 25 percent hay) was offered to the lambs from two weeks of age onwards. The creep-fed lambs were 6.6 kg heavier than the control lambs at weaning age of 60 days. The weight of lambs with creep feeding at 45 days old (19.3 kg) was within the range of weights at the normal weaning time of 56 days old, at ICARDA's flock (mean 19.5 kg). This would offer the possibility to wean the lambs already at an age of 45 days (Rihawi *et al*., 2008). At experimental level, it was shown that milk production out of season to capture higher market prices was possible. Although representing additional costs, producing out of season brought extra benefits to farmers allowing them to recover costs and make profits, because of the better prices of milk products. At experimental level, the extra profit per ewe that could be obtained by producing during an unconventional time, in spite of feeding costs, amounted to 23US$.

In Morocco, in order to alleviate the negative effects of climate change, the government developed several measures and programmes geared at livestock protection. Herders were persuaded to destock gradually, buy feeds to supplement the feed shortage and inoculate livestock. These practices intensified livestock management than before, and they were important to strengthen farmers' and herders' resilience and preparedness against climatic hazards. Short-term sheep fattening and dairy cattle production were trends that became popular. Conservation through the use of feed blocks and pellets gave greater efficiency of use of a wide range of agro-industrial by-products. Their adoption was slow, often because of the lack of knowledge of farmers' problems and expectations. Adaptive research on technologies and management practices, involving relevant practitioners, were needed to provide policy and institutional support for wider adoption of improved production and resource management practices. Some research and development projects based on the farmer participatory approach resulted in improved crop and livestock technologies being successfully transferred. The lesson learned was that technologies and policies that might help ensure sustainable livelihoods and enhance the productive capacity of dry lands everywhere, should be refined and promoted. Moreover, adjusting current feeding strategies or developing new ones which fit with the recent challenges imposed by prolonged droughts and global climate warming were deemed necessary to be considered at the local, national and international levels.

Hudson (2002) conducted a study in the North-West province, a semi-arid zone of South Africa where the potential value of climate forecasting to livestock producers was assessed, where drought-induced losses of secondary production and livestock mortality were major threats to economic stability and human well-being. The study discovered that commercial and communal farmers coped with drought in qualitatively similar ways. The main adaptation measures included selling of animals and buying of fodder. Commercial farmers were more likely to have sold animals outright, whereas communal farmers sold animals to buy fodder for the remaining animals. Whereas few (4%) commercial farmers reported that a single-year drought would be difficult to cope with, 37 percent of communal farmers said that a single-year drought would cause great difficulty. Eight percent of commercial farmers believed their production systems could survive four years of consecutive drought, but no communal farmer predicted surviving more than three years of drought.

Many commercial farmers (72%) and communal farmers (40%) had some access to climate forecasts through television, radio, telephone, or other means. Weekly or monthly forecasts were available to 68 percent of commercial farmers, and to 25 percent communal farmers. In general, farmers considered seasonal forecasts valuable, but not accurate. This was likely related to a seasonal forecast for a severe drought in 1998, which did not come to pass. In overall, about 29 percent of livestock farmers reported using seasonal climate forecasts in their management, with more farmers likely to adopt their use when the predictive power of forecasts improved. Results and feedback from South African livestock producers suggested that a real-time farm model linked with climate forecasting would be a valuable management tool. With the use of a modelling exercise, the study discovered that the coefficient of variation (CV) in rainfall had changed over the past 100 years. The CV of rainfall from approximately 1900 to 1960 was about 24.8 percent and from 1960 onwards, it was about 36.3 percent, which is a big change. This created an impression that the South African livestock farmers had been coping with increased variability of rainfall for quite some time.

Adding value to products by increasing food hygiene, safety and quality was an adaptation strategy in Syria, and it proved to be beneficial to farmers. In Syria there were national reports indicating that the amount of milk sold as fresh milk dropped, as a result of the progressive replacement of fresh sheep milk with cow milk (Iñiguez and Hassan, 2004). As a result of this, there was an increase of more intensive dairy production systems which processed their own milk, particularly yoghurt, rather than selling it as fresh milk at a low price. Yoghurt was prepared in a traditional way and was very much prone to contamination. Farmers reported that the yoghurt was often sour, had poor texture, was crumbled, and had a yeast flavour. All these problems lowered the quality and market value of the yoghurt. Another problem was that the yoghurt was not firm, and as a result it collapsed when transported. Research and workshops (on milk hygiene, improved yoghurt processing and culture management) were conducted on Syrian farmers that depended on sheep milk processing for 48 percent of their income, to improve the quality of their products. As a result of the research, incomes increased because of an additional 5 Syrian pounds per kg that was received compared to yoghurt traditionally prepared. The participatory approach helped farmers to improve their processing skills and marketing of dairy products (Hilali *et al*., 2006). Such simple capacity building activities improved competitiveness of smallholders in the market and helped them to mitigate the effects of climate change through improved income and better shelf-life of their products.

Adaptation measures were also studied in Ethiopia and Tanzania. Adaptation measures in Ethiopia were planting of trees, soil conservation, use of different crop varieties, changing planting dates and irrigation (Deressa *et al.,* 2011). Di Falco *et al.* (2009) also made a similar study in Ethiopia and indicated that farmers did the same practice of changing crop varieties, planting trees, and adopting soil and water conservation measures. Moreover, water harvesting was practised although it was done by only 5 percent of the farmers interviewed. These adaptation measures were similar to adaptation measures that were identified by Mary and Majule (2009) in Tanzania whereby the local people of Tanzania changed planting dates. In addition to that, local people in Tanzania, as adaptation strategy, buried crop residues to increase soil fertility and burned crop residues to control pests. They also used contour ridges to minimize soil erosion and improve root penetration. They diversified by mixed cropping to reduce risk of losses. Dungumaro and Hyden (2010) discovered that in Tanzania pastoralists moved livestock to areas where there was adequate grazing, as a way of adapting to climate change.

2.9 Adaptation challenges

Adaptation to climate change had challenging factors as identified by other researchers. Dungumaro and Hyden (2010) who studied adaptation challenges in Tanzania, identified poverty which was due to lack of employment in rural areas as a challenging factor for adaptation to climate change. This was because poverty limited the means to cope with and adapt to climate change. Continued reliance on subsistence agriculture was among the many factors behind deeper poverty in rural areas of Tanzania. As a result, majority engaged in non-farming activities that had detrimental effects to the environment. Dungumaro and Hyden (2010) also discovered that their engagement did not necessarily help them walk out of poverty but it helped them to support their livelihoods. The study also identified 2.9 percent population growth rate and was primarily rural (i.e. 77 percent), depending on agriculture, animal husbandry, forestry and fishery to support livelihoods. Because farmers in the Tanzania area of study relied heavily on natural resources to support livelihoods, the increase in temperatures and reduced precipitation would lead to overall decline in agricultural productivity and yields. Livestock were also expected to experience shortage of grazing because of reduced rangeland productivity.

Another challenge that was identified in Tanzania was that population increased significantly and impacted negatively on the ability to adapt to climate change. Tanzania has a high population growth rate of 2.9 percent per annum that is brought about by high fertility and declining mortality levels (National Population Policy, 2006). The population of Tanzania has continued to be primarily rural despite the fact that the proportion of urban residents has been increasing over time. Particularly important is the fact that the rural population segment depended heavily on agriculture, animal husbandry, forestry and fishery to support livelihood. All of these activities were dependent on the climate thus exposing the rural community to risk of climate change effects. It should be noted that Tanzania is simply a case in point and not the only country with inadequate adaptive capacity. The IPCC (2001) has emphasized that Africa is characterised by a low adaptive capacity. An additional challenge to the already mentioned challenges was the heavy reliance on natural resources to support agriculture which was Tanzanian's economic mainstay. Climate change such as increased temperatures and reduced precipitation rates were bound to lead to overall reduction in agricultural productivity and yields. Rangeland was also likely to reduce livestock production hence threatening food security and intensifying the risk of famine.

2.10 Adaptation of livestock to climate change

Livestock production remains the springboard in times of shocks for rural communities, although the climate is becoming more variable and unreliable. There is a growing body of literature on the role of livestock in providing pathways out of poverty for poor households. According to Freeman *et al.* (2007), climate-induced shocks often result in negative coping strategies that deplete livestock assets. For many poor people, the loss of livestock assets means collapsing into chronic poverty with long-term effects on their livelihoods. Other studies indicate that diversification of income sources through livestock farming can be a key strategy to escape poverty (Krishna *et al*., 2004; Kristjanson *et al*., 2004). In addition, farmers already have a wealth of indigenous knowledge on how to deal with climate variability and risk.

A wide range of possible adaptation or coping options exists, from technological changes to increase or maintain productivity, through to learning, policies and investment in specific sectors and risk reduction options, which may increase the adaptive capacity of poor livestock keepers. Kurukulasuriya and Rosenthal (2003) defined a typology of adaptation options. The first option was micro-level adaptation options, including farm production adjustments such as diversification and intensification of crop and livestock production, changing land use and irrigation, and altering the timing of operations. The second option was market responses that were potentially effective adaptation measures to climate change, such as insurance and credit schemes, and income diversification opportunities. The third response was institutional and policy changes, such as the removal or putting in place of subsidies, the development of income stabilization options, improvements in agricultural markets, and the promotion of inter-regional trade in agriculture. Washington *et al.* (2006) argued that addressing climate on one time scale might be the best way to approach the informational and institutional gaps that limit progress at another longer time scale, particularly in Africa.

2.11 Climate change and the United Nations Millennium Development Goals (MDGs)

Climate change has been viewed as presenting significant threats to the achievement of the United Nations' MDGs more especially those that are related to eliminating poverty and hunger, and promoting environmental sustainability. The MDGs were established following the Millennium Summit in 2000 with the aim of encouraging development by improving social and economic conditions in the world's poorest countries. Climate change and global poverty have been viewed as running parallel to each other in various studies conducted. Climate change has also been viewed as worsening the poverty that the MDGs are targeting to alleviate. Livestock production is threatened by climate change although it is the popular agricultural activity that is practised by poor rural communities in developing countries.

Firstly, weather-related disasters that have negatively affected livestock production have been viewed as a threat to MDGs. An example is the increased occurrence of droughts with deadly effects on the health of livestock and on the conservation of natural resources. According to Reid and Alam (2005), climate change would cause many semi-arid regions to become hotter and drier with less predictable rainfall. They also predicted climate-induced changes to livestock production. These disasters are expected to affect the poor and delay the Millennium Development Goal of eradicating extreme poverty and hunger. This is confirmed by Rahman *et al.* (2009), who also purported that the impacts of climate change on livestock production would affect poverty reduction activities in attaining the MDGs. The impacts were perceived to be an increase in death rates of livestock. Climate change was also viewed to hamper the production of livestock due to a decrease of grazing lands, decrease in the health status of livestock which eventually would negatively affect meat and milk production. Climate change was also viewed to cause increase in death rates of livestock. All these impacts need to be considered as threats that can slow down the progress of the United Nations' MDGs.

Secondly, various studies have envisaged the emergence of animal diseases due to climate change. According to the report of the thirtieth FAO Regional conference (FAO, 2010b), the risk of heat stress and floods would raise the probability of trans-boundary animal diseases such as Rift Valley Fever and Blue Tongue. A study by Aluwong and Bello (2010), predicted that changes in temperatures and rainfall could increase the incidence of zoonotic diseases together with increased movement of animal species which could affect livestock health.

Lastly, a lot of research that has been conducted points to the poorest countries as the ones that suffer from the negative impacts of climate change (O'Brien *et al*., 2000). Studies also point out that poorer communities have little contribution to climate change but are more vulnerable because of their dependence on livestock production for their livelihoods. Therefore, in addressing poverty and hunger, together with promoting environmental sustainability, climate change challenge needs to be considered.

The above pose a threat to the achievement of the MDG which aims to eradicate extreme poverty and hunger. The target is to halve, between 1990 and 2015, the proportion of people whose income is less than US$1 a day and also halve, between 1990 and 2015, the proportion of people who suffer from hunger. According to Schipper and Pelling (2006), losses to weather-related disasters, meeting the MDGs and implementing a successful response to climate change can only be achieved if they are undertaken in an integrated manner. Secondly, it remains a challenge to influence policy-makers and scholarly communities of the practice to interact more regularly and effectively.

2.12 Conclusion

In this chapter, the literature reveals that climate change is existent and many livestock farmers have become aware in many countries across the globe. Climate change has been perceived in terms of extreme heat, droughts and heavy rains which come at unexpected periods of the year, and resulting in disasters. Conversely, it has been perceived in the form of declining rainfall patterns and rainfall that started later than in normal times. Water sources have been seen drying up to the detriment of livestock production. Climate change has also been perceived in terms of reduction of winter months and change of winter seasons. Extreme heat has been seen as resulting in pest and termite outbreaks causing diseases to livestock. Perceptions have also been in the form of a rise in sea-level, incidences of cyclones and increased pollution. All these observations prove that climate change exists and has been perceived by many countries across the globe.

Climate change impacts have been negative, bringing social and economic instabilities. Climate change has impacted consumer welfare and household economies negatively. The extreme heat and excessive rains have impaired livestock productivity, increased incidences of livestock diseases and reduced household incomes from livestock production. Forage production has been observed to drop in the study and profits from livestock keeping have been perceived to diminish. The most undesirable aspect about climate change is that it has been noticed to affect the poor. The poor have become vulnerable due to lack of resources to adapt to climate change. These negative impacts had negative effects on the economies of the countries.

The livestock sector has been observed to be particularly prone to climate change although it has been the stronghold of countries and many rural communities. Livestock has been kept for income, manure, ploughing and status in rural economies. In the Eastern Cape province livestock production has always been a pillar for household economies. Without livestock production communities may not get incomes for survival. They may also lack manure and draught animals for ploughing. Livestock production has also been perceived as contributing substantially to agricultural GDP as it has been creating employment to a vast majority of rural people. This implies that for economies of countries to thrive, livestock production must not be ignored. It also implies that livestock production has a potential to cushion household economies from all forms of shocks.

Livestock production has also been discovered to contribute to climate change through emissions generated by activities that are involved in the livestock production, such as production of feed. Research has indicated that activities of livestock production make a huge contribution to total anthropogenic GHG emissions on a global scale. The emissions that are generated need to be considered when policy is formulated on climate change.

Adaptation measures have been applied by the countries studied in this research. Some of the adaptation measures were practices that had been conducted for decades without prior knowledge of climate change. The practices included moving stock to greener pastures and where there are sources of water. These practices have been indigenous knowledge for many communities in the areas studied. Some of the adaptation measures were buying of multi-nutrient feed blocks, destocking gradually, inoculating, selling small stock, practising traditional and Christian ceremonies, and also selecting breeds that had adaptive traits for climate change. All these adaptation practices were observed to be effective in the areas studied. Adaptation also had challenges which were identified by other countries. The challenges that were outstanding were poverty that was rife in the rural areas. Other challenges were population increases that significantly impacted on the ability to adapt to climate change, and also heavy reliance on natural resources to support rural livelihoods. These challenges were perceived to have a negative impact on rural economies that have livestock production.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the area where the study took place. It covers the area in square kilometres and where it is situated on the map. The agro-ecological zones are explained together with livestock that are prominent in the zones. Climate is also explained in terms of average annual temperature and mean annual rainfall. This chapter also covers sample selection method and the way in which data was collected. The methods used to analyse data are Principal Component Analysis (PCA), Binary Logistic Regression Model (BLRM) and the Heckman Probit Model (HPM).

3.2 Study area

The study was carried out in the Eastern Cape province which is the second largest province of South Africa's nine provinces as indicated in Figure 3.1. The study was carried out in three district municipalities: OR Tambo, Amatole and Chris Hani. Eastern Cape covers 168, 966 square kilometres in the South East of the country on the Indian ocean coast which is 13, 9 percent of South Africa (SAI, 2010).

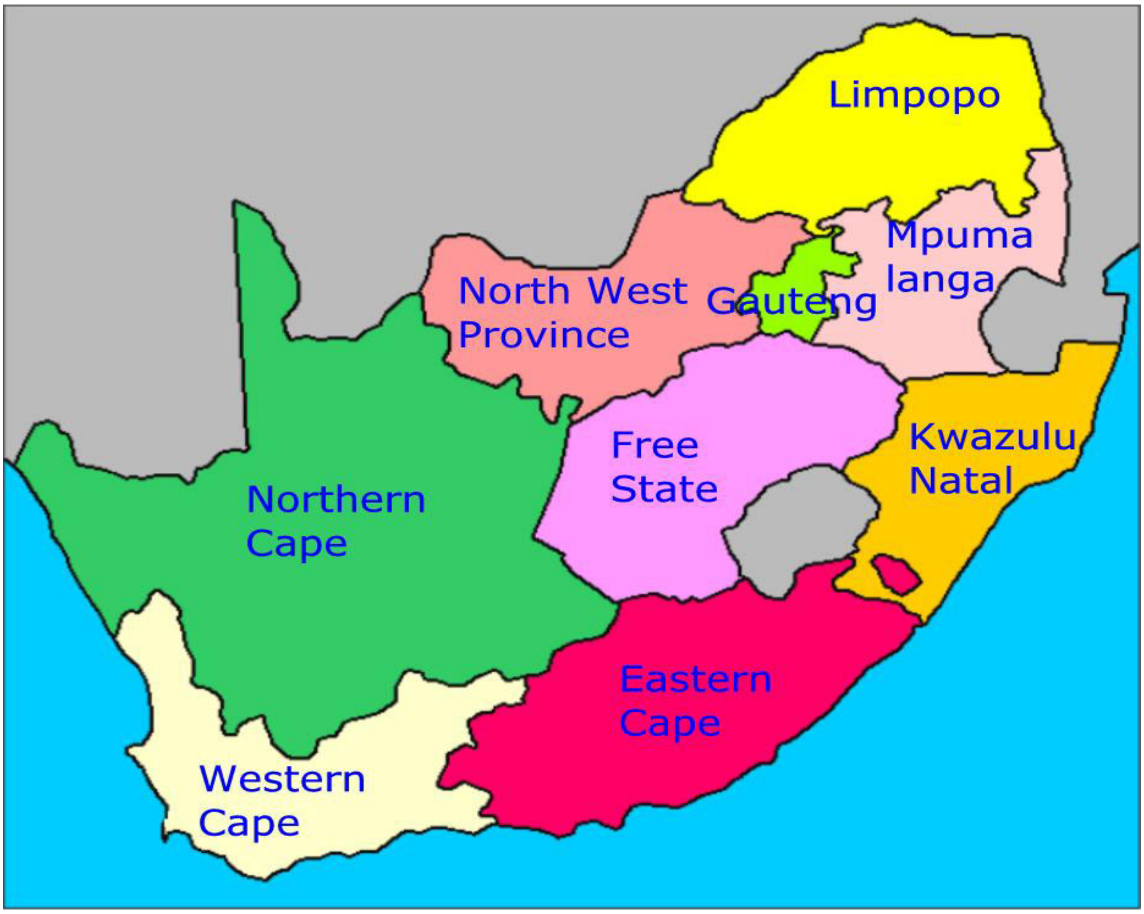


Figure 3.1: South Africa's nine provinces
Source: South Africa Info (2010).

Previously, Eastern Cape formed part of the Cape province and the homelands of the former Transkei and Ciskei. Since the 1994 period of the New South Africa, the province is now made up of 6 district municipalities that in turn consist of 38 local municipalities, and 1 metropolitan municipality. The municipalities are indicated in Figure 3.2.

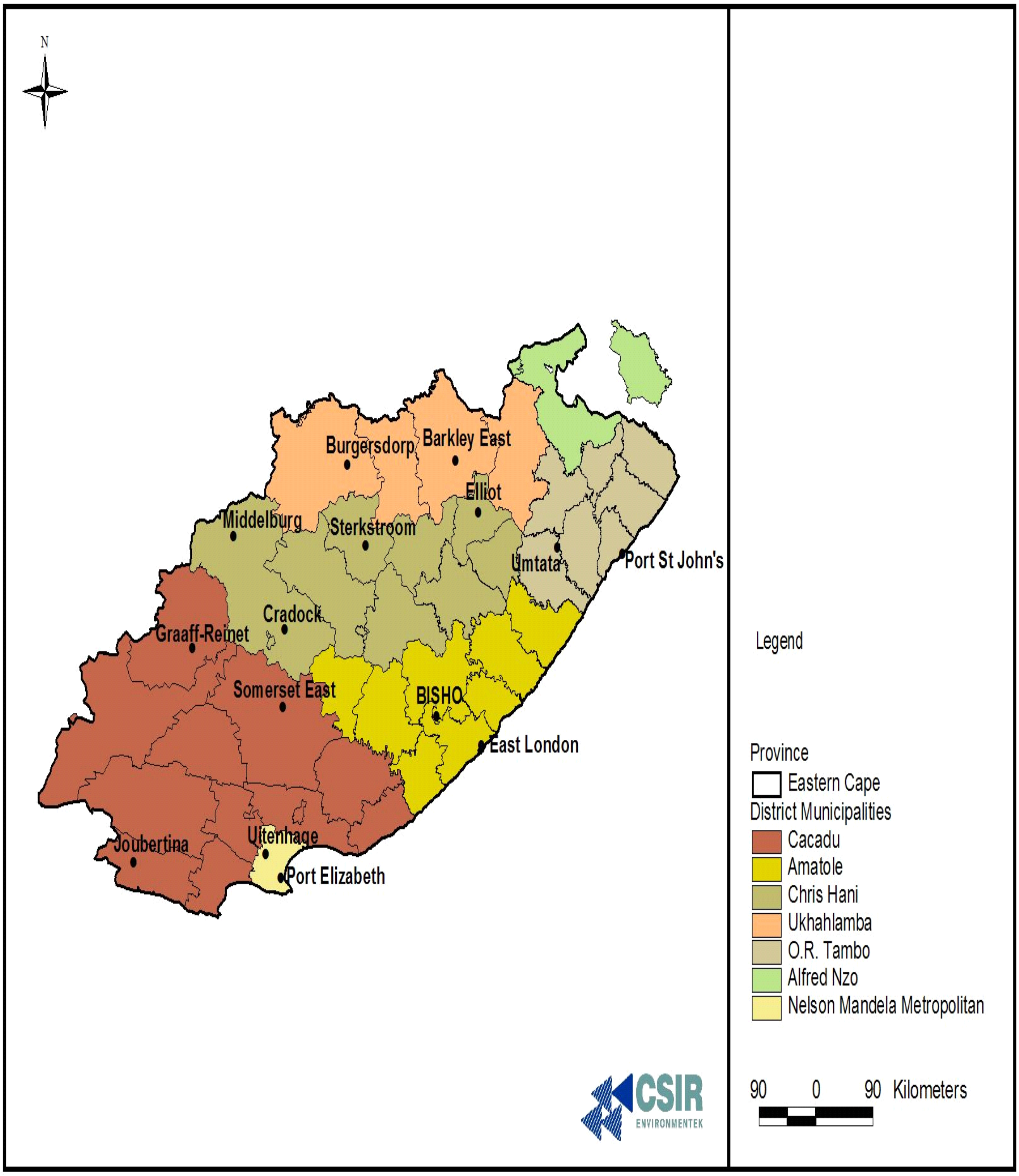


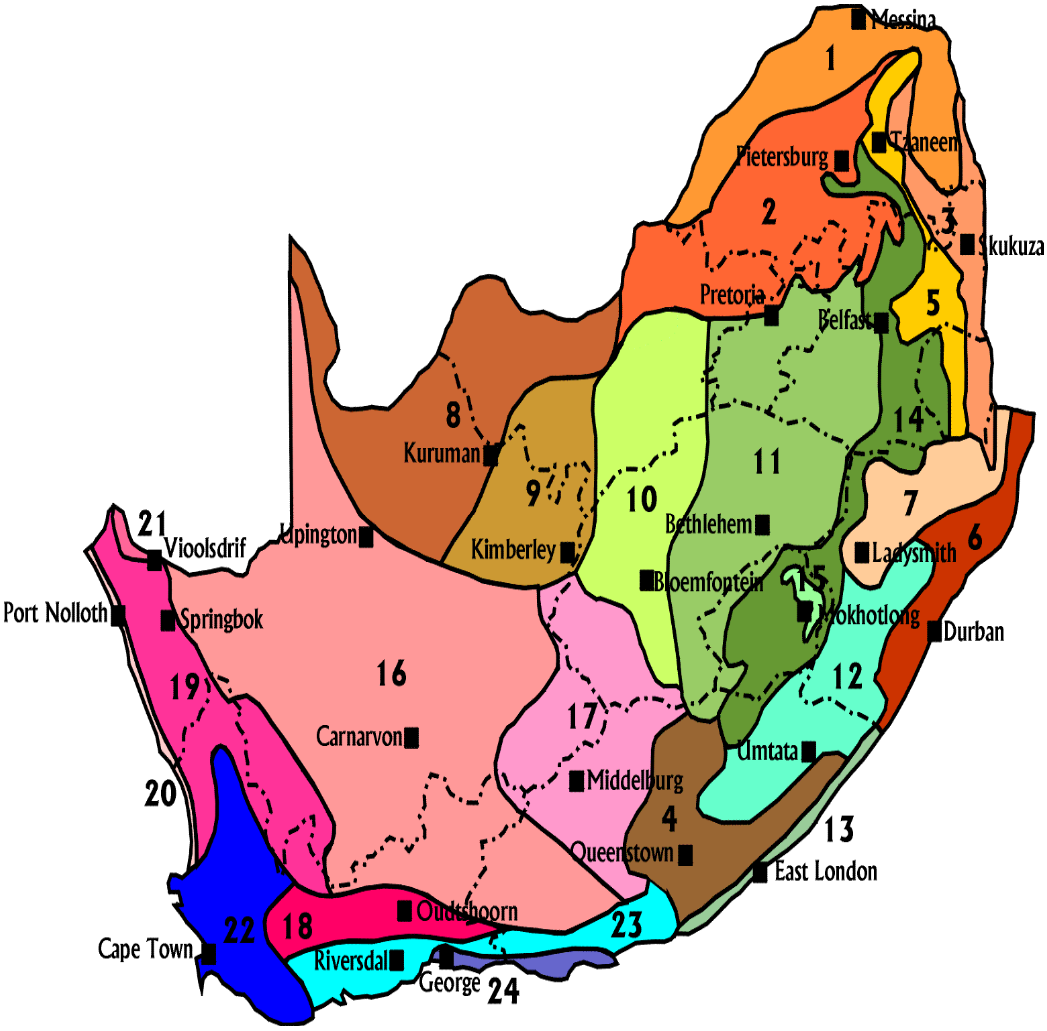
Figure 3.2: The six district municipalities and one metropolitan municipality of the Eastern Cape Province
Source: Municipal Demarcation Board (2002).

The total population of the six district municipalities is 7 130 427 (Municipal Demarcation Board, 2002). This is the structure that was drawn up under the new legislation published in 2000 (Municipal Systems Act No.32 of 2000), in order to establish a new framework of planning, a performance-management system and effective use of resources. It is a new system of decentralizing power. It should enable local communities to voice their opinions and concerns without following long endless procedures.

3.2.1 Agro-ecological zones

South Africa has agro-ecological zones that are diverse as indicated in Figure 3.3. There are areas with relatively dry temperatures which are in the interior. The coastal areas are relatively humid and tend to be beneficial for livestock production. The average annual rainfall is 464 mm per annum compared with the world average of 860 mm per annum (South African Weather Service, 2009). The amount and temporal distribution of rainfall and other climatic factors influence livestock production. The most significant season is the spring/summer season (September to February) which brings rainfall. This is quite beneficial for livestock production because it is heavily dependent on rainfall for grazing.

Cattle-ranching is predominant in the eastern parts of the country where the rangelands generally have a higher carrying capacity. Beef cattle-ranching is the largest contributor to commercial farming income. Sheep are largely concentrated in the drier west and also in the south east of the country. For communal areas, cattle and sheep farming are important, and of the total farming area of South Africa which is 17 percent (for communal area), there is approximately 52 percent of the total cattle population. Communal livestock production contributes insignificantly to formal agricultural output and is mainly confined to the eastern and northern parts of the country.



1. Northern Arid Bushveld 2. Central Bushveld 3. Lowveld Bushveld 4. South-Eastern Thornveld 5. Lowveld Mountain Bushveld 6. Eastern Coastal Bushveld 7. KwaZulu-Natal Central Bushveld 8. Kalahari Bushveld 9. Kalaharu Hardveld Bushveld 10. Dry Highveld Grassland 11. Moist Highveld Grassland 12. Eastern Grassland 13. South-Eastern Coast Grassland 14. Eastern Mountain Grassland 15. Alpine Heathland 16. Great and Upper Karoo 17. Eastern Karoo 18. Little Karoo 19. Western Karoo 20. West Coast 21. North-Western Desert 22. Southern Cape Forest 23. South-Western Cape 24. Southern Cape.

Figure 3.3: The agro-ecological zones in South Africa.
Source: Department of Agriculture, Eastern Cape (2009).

3.2.2 Climate in South Africa

South Africa is regarded as semi-arid because it has a mean annual rainfall of approximately 450 mm (South African Weather Service, 2009). There is, however, wide regional variation in annual rainfall (Figure 3.4), from less than 200 mm in the Richtersveld on the border with Namibia, to more than 1000 mm in the mountains of the South Western Cape.

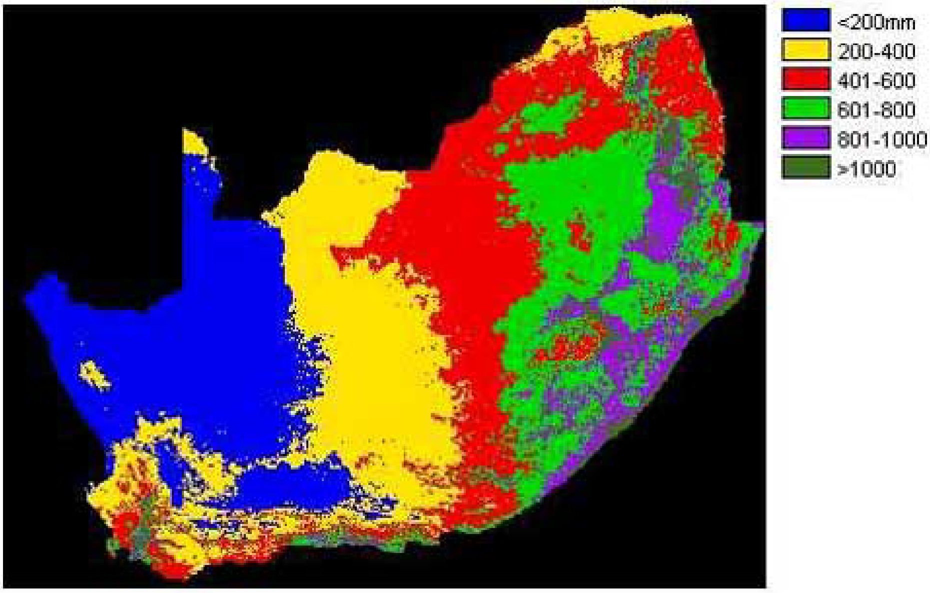


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Figure 3.4: The median rainfall in South Africa.
Source: Department of Agriculture and Land Affairs (2001).

Only 28 percent of the country receives more than 600 mm, and it is the coastal areas which the Eastern Cape province is part of. The uncertainty of the rainfall is best expressed by the co-efficient of variation in annual rainfall (Figure 3.5). The low rainfall regions have the highest co-efficient of variation. Again, Eastern Cape is part of the areas with the low coefficient of variation. Although Eastern Cape has a low coefficient of variation in rainfall, it has been hit the hardest by drought over the years and Agriculture South Africa (AgriSA) termed it the worst drought in the past 130 years.

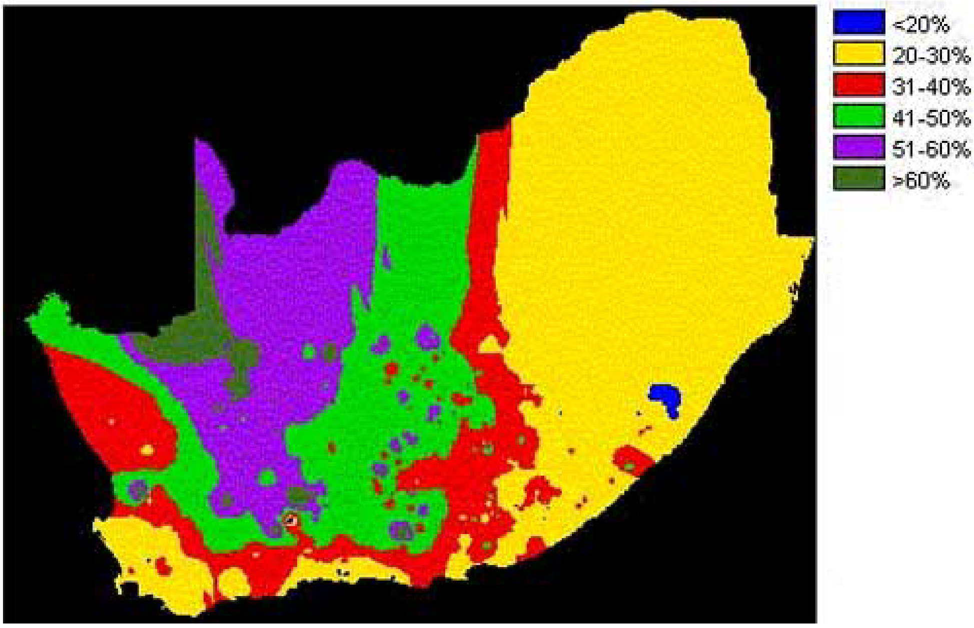

Figure 3.5: The co-efficient of variation in annual rainfall for South Africa.
Source: Department of Agriculture and Land Affairs (2001).

Annual rainfall distribution is skewed such that there is more below average than above average rainfall years, and the median is a more meaningful than the mean. The high seasonal variations are accompanied by high spatial variability, and the annual potential evapo-transpiration may exceed annual precipitation by ratios of up to 20:1, hence drought conditions are a common phenomenon (Schulze, 1997).

3.2.3 Climate in the Eastern Cape

In the Eastern Cape, average annual rainfall has been declining from 2005 to 2009 (Fig 3.6). Estimations from data obtained from the Agricultural Research Council (ARC) in Fig 3.6 indicate a general decline in the average annual rainfall accompanied by a steady increase in average annual temperatures between 2005 and 2009. The general decline in the average annual rainfall during the study period is indicated by the linear average rainfall line, while the general increase in the average temperature during the same period is indicated by the linear average temperature line.

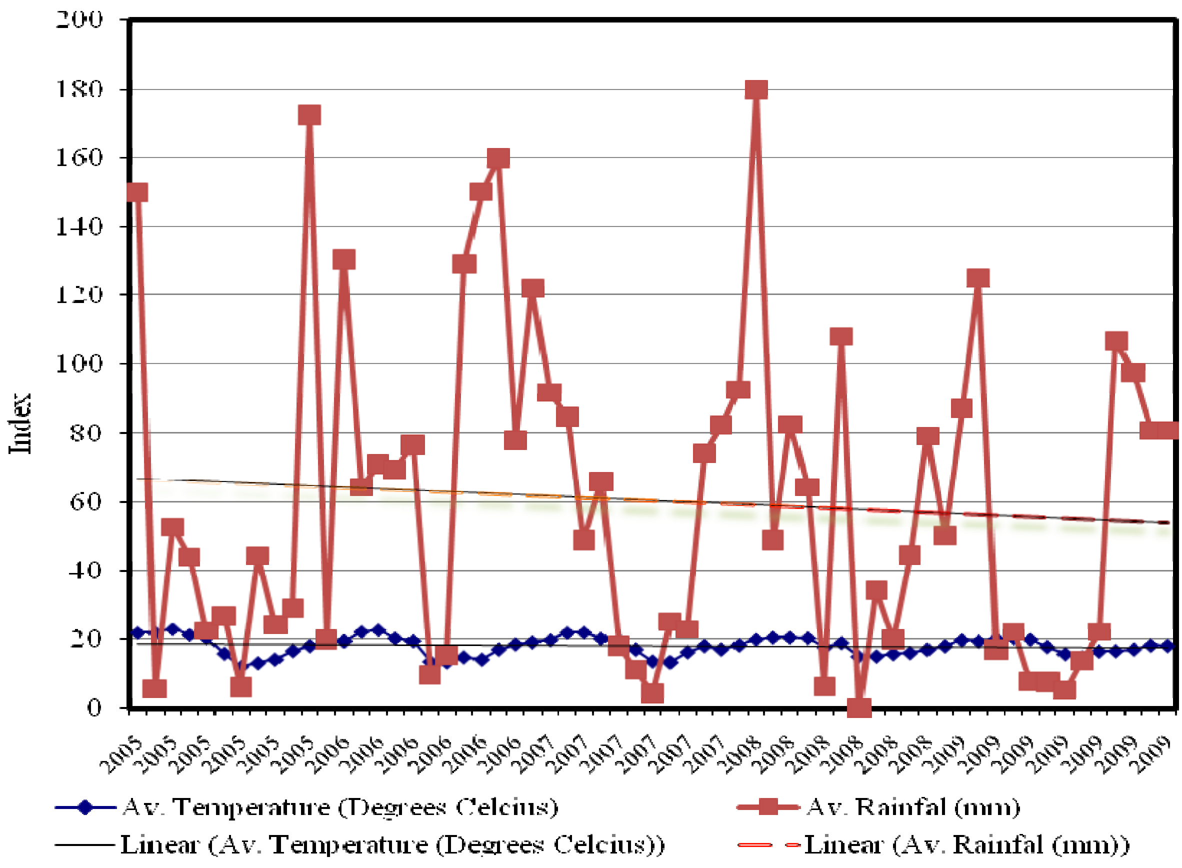

Figure 3:6: Eastern Cape climate for the period 2005-2009.
Source: Estimations from ARC data (2011)

3.3 Sample selection

As part of the study, 500 farmers were selected and they were those who had participated in extension training courses on livestock farming offered by the Department of Agriculture, Eastern Cape, during the 2005 to 2009 year of study. The reason for the selection was that these farmers were most likely able to provide information on climate change and adaptation on their cattle and sheep farming during the period of study. Due to great diversity of extension training programmes, a stratified sampling with proportional representation method was employed to select the farmers covering three of the six district municipalities. Prior to the visit, the researcher notified the Department of Agriculture in the three district municipalities of the Eastern Cape that were going to be surveyed, about the intention to conduct a survey in the area. The procedure that was going to be followed was explained.

3.4 Data collection

Structured questionnaires written in English were used as research tools to collect data. Questionnaires were made simple by use of closed-ended questions. Local concepts were used to avoid ambiguity. Questionnaires were arranged in blocks of topics in a logical flow of questions. They covered generalities about climate change effects, perceptions of cattle and sheep farmers on climate change, adaptation measures used and factors that influenced decisions of the farmers to adapt or not to adapt to climate change.

Suitable interview times were arranged with farmers and permission was obtained from the rural household heads. The researcher, together with extension officers from the Eastern Cape Provincial Departments of Agriculture, conducted the interviews. The local extension officers helped in collecting data because they had a better understanding of the area in terms of farmers that were prominent in keeping cattle and sheep in the area of study. The interviewers explained to the anticipated respondents the purpose of the survey, the importance of their participation and co-operation during the interviews. Interviews were conducted face-to-face with household heads (either male heads or female heads) in their homes or with an adult that was at home in the absence of household heads. The local extension officers and the researcher translated the questions into the local language of the area, isiXhosa, while conducting interviews. The size of household ranged from 4 to 12 members living at home or living away from home (with financial or decisional connection with the household).

After collecting data, the first step was to transfer it onto a spreadsheet using the Statistical Package for Social Sciences (SPSS) 17.0 version. According to Kumar (1996), it is important that the information obtained should be in the language that the computer will assimilate when a computer will be used to analyse it. It is for this reason that SPSS was used to capture data in order to analyse it.

3.5 Methods of data analysis

In analysing the data, variables that were the most representative of the study (effects of climate change on cattle and sheep production, perceptions on climate change and factors that influenced decisions to adapt to climate change) were selected. Preliminary descriptive statistics of the variables selected were performed and further statistical analysis was conducted. Three types of analysis were employed in the study. They were Principal Component Analysis (PCA), Binary Logistic Regression Model (BLRM) and the Heckman Probit Model (HPM). The PCA was used to identify groups of inter-correlated variables in order to examine hidden interrelationships amongst them. It was also used to get variables that represented different patterns of perceptions and adaptations by cattle and sheep farmers in the area of study. The BLRM was used to determine cattle and sheep farmers' decision to adapt or not to climate change. This method has been used by researchers to analyse similar studies on livestock farmers' choices in decision-making on the impacts of climate change (Seo *et al.*, 2005). The HPM was used to estimate the determinants of an individual livestock farmer's decision to select adaptation. This model has been used in similar studies that determine adaptation to climate change (Maddison, 2007; Bayard *et al.,* 2006 and Deressa *et al*., 2011).

3.6 Conclusion

In this chapter the area where the study took place was described. The agro-ecological zones together with prominent livestock were explained. Climate was described in terms of mean annual rainfall and average annual temperatures. This chapter also covered sample selection methods and the way in which data was collected and analysed. It was concluded that the study area in Eastern Cape was experiencing some form of climate change. This was confirmed by the average annual temperatures that were gradually increasing between 2005 and 2009. Average annual rainfall that was declining between the periods 2005 and 2009 also stood as testimony to climate change. The stratified sampling with the proportional representation method that was employed in sample selection, made the respondents to be accurate representation of the study area. The way in which data was collected (primary data) and the use of local concepts made the data to be authentic. The three methods that were used to analyse data i.e. PCA, BLRM and HPM were employed in order to get a true understanding of climate change and adaptation among the cattle and sheep farmers in the area of study in the Eastern Cape. In conclusion, it is important to note that the methods that were employed were intended to provide an understanding and reflection of the effects of climate change on cattle and sheep farming in the study area. They were also anticipated to provide an understanding of the adaptation measures that were adopted by cattle and sheep farmers in order to alleviate the effects of climate change.

CHAPTER 4

PERCEPTIONS ON CLIMATE CHANGE AND ADAPTATION

"Our rural communities suffer a serious dearth of information that would help actualise themselves. A greater effort must therefore be made to bring awareness of the implications of climate change to the communities and what they need to do in order to protect or reorganize their livelihoods." Nontlantla Skenjana (2011).

4.1 Introduction

In the Eastern Cape, livestock farming is an important agricultural practice although it is mostly rain-fed. Livestock ownership is the wealth of the farmers whether they are educated or not. Livestock is used when business transactions are undertaken such as paying of dowry and exchanging livestock for cash to carry out household obligations, such as children's education. Farmers use livestock for ploughing purposes. They also use droppings from livestock as manure for farming and as fuel. Furthermore, livestock is used for home consumption but on a very limited scale. The Eastern Cape has the highest percentage of livestock especially cattle and sheep compared to the other eight provinces of South Africa. In the Eastern Cape, particularly in the former homelands of Transkei and Ciskei, small-scale livestock farming is quite prominent (Nkonki, 2007).

In South Africa, nearly 80 percent of agricultural land is mainly suitable for extensive livestock farming (NDA, 2003). Livestock are also kept in other areas, usually in combination with other farming enterprises. Numbers vary according to weather conditions. Stockbreeders concentrate mainly on developing breeds that are well adapted to diverse weather and environmental conditions. The livestock sector contributes up to 49 percent of agricultural output and by mid-2007, there were 13.5 million cattle, 24.9 million sheep (South Africa online, 2010). South Africa normally produces 85 percent of its meat requirements, while 15 percent is imported from Namibia, Botswana, Swaziland, Australia, New Zealand and Europe (South Africa online, 2010). Cattle are the generally preferred livestock species, and are important for draught power, but economic and ecological conditions often limit the possibilities of cattle ownership. Sheep are widely distributed in communal areas, with a few communities in the high elevation regions of the Eastern Cape focusing on sheep only (Palmer and Ainslie, 2002).

Studies conducted by Deressa *et al.* (2009) revealed that Africa's agriculture is negatively affected by climate change. This is also confirmed by Apata *et al.* (2009) who maintained that Africa is generally acknowledged to be the continent most vulnerable to climate change. The weather is erratic and unreliable to livestock farmers. This calls for livestock farmers to be aware of the effects of weather patterns in the immediate and long terms. It also calls for adaptation measures that can be taken to curb the negative effects of climate change on livestock production. According to Morton (2007), climate change effects are felt in developing countries among livestock farmers that are referred to as subsistence or smallholders. Furthermore, studies have revealed that small farm sizes, low technology and low capitalization increase the vulnerability of livestock production. Fischer *et al.* (2005) asserted that developing countries had been more vulnerable to climate change than developed countries because of the predominance of agriculture in their economies and scarcity of capital for adaptation measures. Todaro and Smith (2009) concluded that the worst impact of climate change would be felt by the poor.

Several studies conducted to examine perceptions of livestock farmers on climate change showed that farmers had different perceptions on climate change. Studies by Diggs (1991) found out that approximately three-quarters of all livestock farmers surveyed in the Great Plains had different perceptions on change in climate. Another study conducted by Ishaya and Abaje (2008) in Nigeria, revealed that livestock farmers perceived climate change to have occurred over the years due to diverse human activities. A study by Mertz *et al.* (2009) in Sahel, Senegal, indicated that livestock farmers were aware of the climate variability and identified wind and occasional excess rainfall as the most significant factors. According to Gbetibouo (2006), 91 percent of livestock farmers in the Limpopo basin perceived changes in temperatures over 20 years to be most significant in climate change. In the study by Kurukulasuriya *et al.* (2006), it was concluded that livestock farming in African countries with diverse climatic zones had experienced decline in revenues with rise in temperatures. Revenues from livestock sales only increased with increased precipitation. Deressa (2007) indicated that large numbers of livestock farmers perceived drought and windy weathers to be significant in climate change. Adaptation strategies have been seen to differ among the countries studied but some similarities have been found to exist in certain areas. In Sahel, livestock farmers kept animals in stables and replaced draught horses with cattle which were cheaper to feed as measures of adaptation (Mertz *et al.,* 2009). In the case of smallholder livestock farmers in Zimbabwe, adaptation measures undertaken included a change from exotic to indigenous breeds (Mutekwa, 2009).

4.2 Objectives

The objective of this chapter was to examine the perceptions of cattle and sheep farmers on climate change and adaptation. It was also to examine adaptation measures that cattle and sheep farmers employed in order to deal with climate change. The rest of the chapter is organised as follows: In section 4.3, the hypothesis of the study is presented. In section 4.4 the methodology that was employed is specified. Section 4.5 presents results in the form of descriptive statistics followed by Principal Component Analysis (PCA) and discussion of results. Section 4.6 concludes the chapter.

4.3 Hypothesis

The hypothesis was that different perceptions of factors affecting climate change could be grouped into drought and windy weather patterns, information and adaptation, climate change and extension services, cattle and sheep production and temperature using PCA.

4.4 Methodology

4.4.1 Analytical technique: Principal components (PC) analysis

The PC analysis was used to transform the given set of variables, $X_1, X_2, ...X_k$, into a new set of composite variables that were orthogonal to or uncorrelated with each other. The objective was to identify groups of inter-correlated variables in order to examine hidden interrelationships amongst them (Manly, 1990). Thus, the PC analysis was employed to discover and finally summarise pattern of inter-correlation among variables. In this study, the aim of the PC analysis was to convert the original set of variables, X_j (j=1, 2, k) into a new set of uncorrelated variables called *principal components*, PC_i (i=1,2 ...,k), which were linear combinations of original variables (Koutsoyiannis, 1972):

$PC_1 = a_{11}X_1 + a_{12}X_2 + ... + a_{1k}X_k$

$PC_2 = a_{21}X_1 + a_{22}X_2 + ... + a_{2k}X_k$

. . . .

. . . .

$PC_k = a_{k1}X_1 + a_{k2}X_2 + ... + a_{kk}X_k$

Where PC_i= the *i*th principal component, a_{ij}= component loadings (coefficients) and X_j= original variables, (Koutsoyiannis, 1972). It should be noted that principal components can be extracted from the raw values of the X_j's, or from their standardised values. In this study, the latter method was employed as the units used to measure the original variables differed (Koutsoyiannis, 1972). In the PC analysis, the component loadings (a_{ij}), are chosen so that the principal components satisfy two conditions:

(a) principal components are uncorrelated (orthogonal); and

(b) first principal component (PC_1) accounts for the maximum possible proportion of the total variation in the X_j's, the second principal component (PC_2) accounts for the maximum of the remaining variation (var) in the X_j's and so on. Thus, var $(PC_1) \geq$ var $(PC_2) \geq$ var $(PC_3) \geq \ldots \geq$ var (PC_p), where var (PC_i) expresses the variance of PC_i in the data set being considered. Var (PC_i) are also called the *eigenvalues, eigen vectors, characteristic vectors* or *latent vectors* of PC_i. When using PC analysis, it is hoped that the eigenvalues of most of the PCs will be so low as to be virtually negligible. Where this is the case, the variation in the data set can be adequately described by means of a few PCs where the eigenvalues are not negligible. Accordingly, some degree of economy is accomplished as the variation in the original number of variables (X variables) can be described using a smaller number of new variables (PCs).

4.5 Results and discussions

This section summarises farmers' perceptions on climate change and the adaptation that they considered appropriate to these changes. In Table 4.1, descriptive statistics of the variables that indicated perceptions on climate change and adaptation by cattle and sheep farmers were provided. The results indicated that 60 percent of the respondents received some information on climate change. The type of information that they received was mostly through local radios indicated by 54. 3 percent of respondents. Extension service on climate change was received by only 25. 7 percent of respondents. The increase in temperatures between 2005 and 2009 was observed by 85. 7 percent of the respondents and from observations, drought was predominant. Cattle numbers were perceived to have decreased and this was confirmed by 82. 9 percent of respondents.

In this study, the first presentation of results using the PC analysis was to decide how many PCs should be retained. $PC_{1,}$ the first PC, the one with the largest eigenvalue of 29.419 that described 29.419 percent of the total variation was considered. This proportion of the first PC was considered to describe an insufficient percentage of the total, hence the second PC to the fifth PC was also considered. In combination with the first PC, this encompassed a larger percentage of the total variation (79.148 %). Sufficient percentage is present if no more than 5 or 6 components explain 70 to 80 percent of the total variation.

The second presentation used to assess the adequacy of the number of PCs was the eigenvalue-one criterion, also known as the Kaiser criterion, in which only the PCs where eigenvalues were $\geq$ 1 were retained. The rationale for this criterion was that since each observed variable contributed one unit of variance to the total variance in the data set, any component that displayed an eigenvalue of greater than 1 was accounting for a greater amount of variance than had been contributed by one variable. Such a component was therefore accounting for a meaningful amount of variance, and was worthy of being retained. On the other hand, any principal component with an eigenvalue less than 1 contained less information than one of the original variables and so was not worth retaining. The results of the PC analysis are presented in Table 4.2.

The third presentation was to determine the number of PCs to be retained from the scree graph also known as scree plot (Fig. 4.1). In the scree plot, eigenvalues were plotted against PC numbers. The component numbers were listed on the x-axis, whilst the eigenvalues were listed on the y-axis. The PCs that were retained were those on the slope of the graph before the decrease of eigenvalues levels off to the right of the plot. Using this criterion, 5 PCs were retained in the analysis of this study. The different factors extracted represented different patterns of perceptions of cattle and sheep farmers on climate change and adaptation in the Eastern Cape province. The grouping of the original variables was done by observing the magnitude of the factor loadings. The dominant loadings were presented in bold (Table 4.2). Each PC was considered a weighted linear combination of the variables and was written with the heavy loadings and given the most descriptive names.

Principal Component 1 (PC_1) contributed to 29.419% of the variations with an *eigen* value of 29.419 in the variables included and represented cattle and sheep farmers who were aware of drought between 2005 and 2009 (Table 4.1). All the coefficients were positive indicating a positive correlation among the variables. The drought and windy weather PC equation between 2005 and 2009 could be represented as follows: Drought and windy weather patterns: (PC_1) = $0.836X_5 + 0.903X_6 + 0.912X_7 + 0.526X_8 + 0.700X_9 + 0.604X_{10}$.

Principal Component 2 (PC_2) contributed to 17.874 percent of the variations with an eigen value of 47.293 in the variables included and represented cattle and sheep farmers who received information about climate change and adapted. The information and adaptation PC equation between 2005 and 2009 could be represented as follows: Information and adaptation (PC_2) = $0.758X_1 + 0.747X_2 - 0.691X_{12} - 0.678X_{13}$

Principal Component 3 (PC_3) contributed to 13.448 percent of the variations with an eigen value of 60.741 in the variables included and represented cattle and sheep farmers who received extension services on climate. Among these farmers, 25.7 percent received extension services on climate change and adaptation. The information on the provision of extension serves on climate change and adaptation PC equation between 2005 and 2009 could be represented as follows: Climate change extension service (PC_3) = $0.809X_3$.

Principal Component 4 (PC_4) contributed to 9.765 percent of the variations with an eigen value of 70.506 in the variables included and represented cattle and sheep farmers who received intensive cattle and sheep production as indicated by the heavy loading (67%) of the coefficient. The wind and drought conditions between 2005 and 2009 heavily affected these farmers as indicated by 82.9 percent of farmers indicating that their cattle and sheep production decreased during the period (Table 4.2). The information on intensive cattle and sheep production PC equation between 2005 and 2009 could be represented as follows: Cattle and sheep production (PC_4) = $0.670X_{11}$.

Table 4.1 Perceptions of cattle and sheep farmers on climate change and adaptation

Variable	%	Mean	Std dev.	Variance
Do you have information about climate change	(X_1)	1.40	0.497	0.247
Yes	60.0			
No	40.0			
What type of information (X_2)		4.09	1.579	2.492
Flyers	2.9			
Magazines	2.9			
Radio	54.3			
Other	2.9			
None	37.1			
Do you have extension service on climate change (X_3)		1.74	0.443	0.197
Yes	25.7			
No	74.3			
How were temperatures in 2005 – 2009 (X_4)		1.17	0.453	0.205
Increased	85.7			
Decreased	11.4			
Stayed the same	2.9			
Are you aware of 2003/2004/2005 drought (X_5)		1.29	0.458	0.210
Yes	71.4			
No	28.6			
Type of weather in 2005 (X_6)		1.77	1.114	1.240
Drought	57.1			
Winds	25.7			
Other	17.1			
Type of weather in 2006 (X_7)		1.83	1.200	1.440
Drought	60.0			
Winds	17.1			
Floods	2.9			
Other	20.0			
Type of weather in 2007 (X_8)		2.74	1.221	1.491
Drought	20.0			
Winds	28.6			
Floods	8.6			
Other	42.9			
Type of weather in 2008 (X_9)		2.11	1.105	1.222
Drought	37.1			
Winds	31.4			
Floods	14.3			
Other	17.1			
Type of weather in 2009 (X_{10})		1.89	1.051	1.104
Drought	48.6			
Winds	25.7			
Foods	14.3			
Other	11.4			
Cattle production (X_{11})		2.31	1.183	1.398
Increased	5.7			
Decreased	82.9			
Numbers stayed the same	2.9			
n/a	8.6			
Adaptation measures(X_{12})		1.83	1.445	2.087
No adaptation	71.4			
Sold livestock	5.7			
Planted supplementary feed	14.3			
Other	8.6			
Reasons for non adaptation (X_{13})		4.71	1.888	3.563
Lack of information	2.9			
Lack of money	22.9			
Lack of inputs	45.7			
Lack of property	8.6			
Other	17.1			
n/a	2.9			

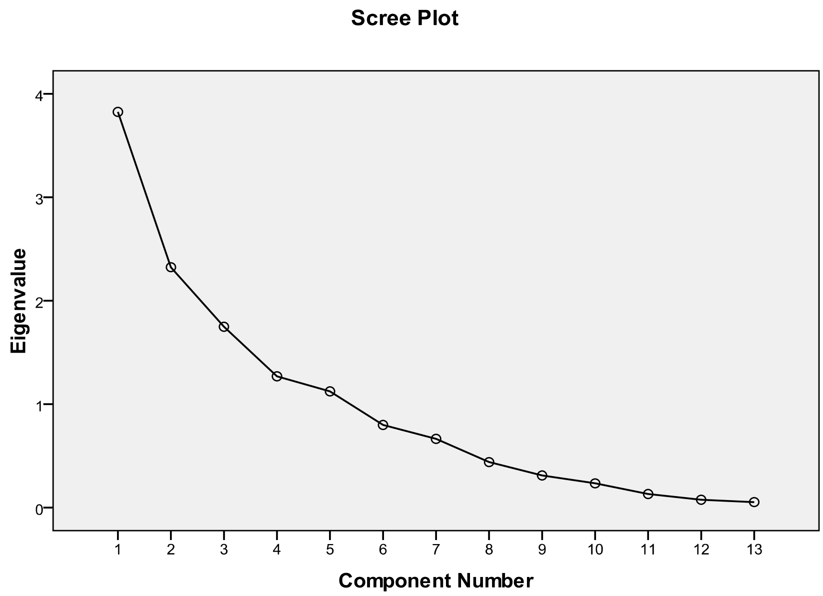

Figure 4.1 1 Screen plot of Principal Components and Eigen Values

Principal Component 5 (PC_5) contributed the least (8.642%) of the variations with an eigen value of 79.148 in the variables included, and it represented cattle and sheep farmers who regarded temperature to be the dominant factor affecting climate change between 2005 and 2009. From Table 4.1, 85.7 percent of farmers perceived an increase in temperature to dominate during the study period. The perception on temperature change and adaptation PC equation between 2005 and 2009 could be represented as follows: Temperatures (PC_5) = $0.637X_4$.

Table 4.2: Principal component (PC) retained and percentage of variance explained/Factor analysis

Variables	Factor loadings: PC_1	PC_2	PC_3	PC_4	PC_5
Information about climate change (X_1)	-0.335	**0.758**	0.445	0.117	0.115
Type of information (X_2)	-0.358	**0.747**	0.352	0.263	0.255
Extension service on climate changes (X_3)	-0.008	0.161	**0.809**	-0.138	-0.254
Temperature (X_4)	0.017	0.367	**-0.495**	-0.106	**0.637**
Aware of drought (X_5)	**0.836**	0.159	0.084	0.273	0.033
Type of weather in 2005 (X_6)	**0.903**	0.051	0.150	0.143	-0.061
Type of weather in 2006 (X_7)	**0.912**	-0.033	0.059	0.090	-0.037
Type of weather in 2007 (X8)	**0.516**	-0.031	0.302	-0.434	0.550
Type of weather in 2008 (X_9)	**0.700**	0.211	-0.164	-0.184	0.001
Type of weather in 2009 (X_{10})	**0.604**	0.127	-0.009	0.432	0.033
Livestock production (X_{11})	-0.275	0.040	-0.314	**0.670**	0.093
Adaptation measures (X_{12})	-0.199	**-0.691**	0.370	0.043	0.454
Why not adapt (X_{13})	-0.049	**-0.678**	0.374	0.440	0.223
Eigen value	29.419	47.293	60.741	70.506	79.148
% variance	29.419	17.874	13.448	9.765	8.642
Cumulative %	29.419	47.293	60.741	70.506	79.148

N=500

4.6 Conclusion

In this chapter, perceptions of cattle and sheep farmers on climate change and adaptation were analysed using information from livestock farmers between 2005 and 2009 farming season. Preliminary descriptive statistics indicated that farmers interviewed had different perceptions on climate change and adaptation measures between 2005 and 2009. Findings also revealed that cattle production decreased during 2005 to 2009. Further analysis using principal components showed that the different perceptions of factors affecting climate change could be grouped into: (i) drought and windy weather patterns; (ii) information and adaptation; (iii) climate change and extension services; (iv) cattle and sheep production; and (v) temperature. The results call for further analysis to investigate the different adaptation measures that could be used by cattle and sheep farmers during those weather conditions.

In conclusion, the cattle and sheep farmers in the area of study indeed had different perceptions on climate change. This meant that with the change in climate, the farmers would respond differently to climate change according to the way they perceived climate change. Perceptions should play a significant role in adaptation measures that will be employed by the cattle and sheep farmers. Perceptions should also play a significant role in decisions by government to intervene.

Media has been observed to be instrumental in informing cattle and sheep farmers about climate change. The radio was the most used source of information. Extension services were not influential about climate change and adaptation as very small percentage (25.7%) of respondents received extension services about climate change. The radio in this study therefore, seems to be more influential on information dispersion and it seems to be widely used more than any other form of media. This may be because of a greater incidence of illiteracy in the study area which is predominantly rural.

CHAPTER 5

CLIMATE CHANGE AND ADAPTATION

"*The key question is whether farmers have access to the best means of adapting to climate change in their local context*," Ariel Dinar (2008).

5.1 Introduction

Several studies have shown significant and alarming negative impacts of climate change and adaptation of livestock farmers in different parts of the world (Hassan and Nhemachena, 2008; Deressa *et al*., 2005; Kabubo-Mariara, 2007). Various research findings indicate that the damaging effects of global temperature is increasing and most damages are predicted to occur in sub-Saharan Africa where the region already faces average high temperatures and low precipitation, frequent droughts and scarcity of both ground and surface water (IPCC, 2001).

In developing countries of Africa, including South Africa, global warming studies predict that by the year 2100 increase in temperature will be in the region of 4^0C. Previous studies on climate change and adaptation of livestock farmers have shown that climate change affects livestock farming directly and indirectly (Kabubo-Mariara, 2008). Direct effects have been observed to include retardation of animal growth, low quality animal products including hides and skins, and animal production in general. Indirect effects have included general decline in quantity and quality of feedstuffs for example, pasture, forage, grain severity and distribution of different species of livestock, and other effects such as increase in livestock diseases and pests. In particular, extreme temperatures resulting in drought had devastating effects on livestock farming and the vulnerable rural poor have been left with marginal pasture and grazing lands (Kabubo-Mariara, 2005).

The vulnerability of livestock farming to climate change is an important concern in the world and in many African countries especially in South Africa where many rural households depend on livestock for wealth. Over the last decade when global warming was found to be detrimental to fauna and flora in the world, the relative contribution of the agricultural sector, including livestock numbers had declined. There are studies on the impact of climate change in agriculture in South Africa and in other developing countries. However, there is limited research on its impact on livestock production particularly, cattle and sheep farming. Moreover, few studies have been undertaken especially at the provincial and district levels (Hassan and Nhemachena, 2008).

5.2 Objectives

This chapter examined cattle and sheep (livestock) farmers' decision to adapt or not to climate change in three district municipalities of the Eastern Cape. The main objective was to investigate the factors that affected choices of adaptation by households who kept cattle and sheep. The rest of the chapter is organised as follows: In section 5.3 hypothesis of the study is stated. In section 5.4 the empirical model which is BLRM is specified and employed. Section 5.5 presents results in the form of descriptive statistics followed by BLRM results and discussion of results. Section 5.6 concludes the chapter.

5.3 Hypothesis

The hypothesis tested was that the most significant factors that were likely to affect climate change and adaptation would be non-farm income, type of weather perceived by farmers, livestock ownership, access to credit, distance to weather stations, distance to input markets, adaptation choices and annual average temperature.

5.4 Empirical model

The BLRM was used to determine cattle and sheep (livestock) farmers' decision to adapt or not to climate change. This method has been used by researchers to analyse similar studies on livestock farmers' choices in decision-making on the impacts of climate change (Seo *et. al.*, 2005). The main advantage of the BLRM over other models of discrete and limited dependent variables is that it allows the analysis of decisions across two categories, allowing the determination of choice probabilities from different categories. In addition, its likelihood function, which is globally concave, makes it easy to compute. However, the main limitation is the independence of irrelevant alternative properties, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternatives in the available choice selections (Deressa *et. al.,* 2009).

In BLRM, a single outcome variable Y_i *(i=1, ...,n)* follows a Bernoulli probability function that takes on the value 1 with probability P_i and 0 with probability 1-P_i. P_i/1-P_i and is referred to as the *odds* of an event occurring. P_i varies over the observations as an inverse logistic function of a vector X_i, which includes a constant and *K* explanatory variables (Greene, 2003). The Bernoulli probability function can be expressed as:

$$Y_i \Theta Bernoulli(Y_i / P_i) \qquad (1)$$

or

$$In\left[\frac{P_i(Y_i=1)}{1-P_i(Y_i=1)}\right] = In\ (Odds) = \alpha_0 + \sum_{k=1}^{k}\beta_k X_{ik} \qquad (2)$$

Equation (2) above is referred to as the log odds and also the logit and by taking the antilog of both sides, the model can also be expressed in odds rather than log odds, i.e.

$$Odds = \left[\frac{P_i(Y_i=1)}{1-P_i(Y_i=1)}\right] = exp\left[\alpha_0 + \sum_{k=1}^{k}\beta_k X_{ik}\right] \qquad (3)$$

or

$$= e^{\alpha+\sum_{k=1}^{k}\beta_k X_{ik}} = e^{\alpha_0} * \prod_{k=1}^{k} e^{\beta_k X_k} = e^{\alpha_0} * \prod_{k=1}^{k}\left(e^{\beta_k}\right)^{X_k} \qquad (4)$$

There are several alternatives to the BLRM that might just be as plausible in a particular case. However, as stated above, the BLRM is comparatively easy from a computational point of view. There are many tools available which can be used to estimate logistic regression models but in practice, the BLRM tends to work fairly well. If either of the odds or the log odds is known, it is easy to figure out the corresponding probability which can be written as:

$$P = \left[\frac{odds}{1+odds}\right] = \left[\frac{\exp(\alpha_0 + \beta' X)}{1+\exp(\alpha_0 + \beta' X)}\right] \quad (5)$$

The unknown α_0 is a scalar constant term and β' is a K x 1 vector with elements corresponding to the explanatory variables. In this study, the parameters of the model were estimated by maximum likelihood. This means that the coefficients that made the observed results most likely were selected. The likelihood function formed by assuming independence over the observations can be written as:

$$L(\alpha,\beta) = \prod_{i=1}^{n} P_{x_i}^{Y_i}(1-P_{x_i})^{1-Y_i} \quad (6)$$

To random sample (x_i, y_i), $i=1, 2, ..., n$, by taking logs and using equation (2), the log-likelihood simplified to:

$$In[L(\alpha_0,\beta)] = \sum_{i=1}^{n}\{y(\alpha+\beta x) - In(1+\exp(\alpha+\beta x)\} \quad (7)$$

The estimator of unknown parameter α and β can be gained from the following equations by means of maximum- likelihood estimation.

$$\frac{\delta In[L(\alpha_0,\beta)]}{\delta\alpha_0} = \sum_{i=1}^{n}\left| y_i - \frac{\exp(\alpha+\beta x)}{1+\exp(\alpha+\beta x)} \right. = 0 \quad (8)$$

$$\frac{\delta In[L(\alpha_0,\beta)]}{\delta\beta_0} = \sum_{i=1}^{n}\left| y_i - \frac{\exp(\alpha+\beta x)}{1+\exp(\alpha+\beta x)} \right. = 0 \quad (9)$$

Since equations (8) and (9) are non-linear, the maximum likelihood estimators must be obtained by an iterative process, such as the Newton-Raphson or Davidson-Flecher-Powell or Berndt-Hall-Hall-hausman algorithm (Greene, 2003).

A statistical model based on likelihood ratio (LR) was deemed appropriate. This ratio was defined as follows:

$$LR = 2(LogL_R - LogL_U)$$

Where $LogL_u$ was defined as the log-likelihood for the unrestricted model and $LogL_r$ was the log-likelihood for the model with k parametric restrictions imposed. The likelihood ratio statistic follows a chi-square (χ^2) distribution with k degrees of freedom.

5.5 Results and discussion

The descriptive statistics of the variables used in the model are presented in Table 5.1. The table gives the mean values, standard deviation and variance of the dichotomous endogenous variable (adaption and no adaption) and the exogenous variables used in the binary logistic model. Table 5.2 presents the results of the estimated model. The estimated model indicated classification rates of 85.4 percent for no adaptation, 90.6 percent for adaptation and an overall classification rate of 88.7 percent. These results indicate the degree of accuracy of the model and therefore, the reliability of the resulting estimated coefficients with their accompanying statistics. From the data, the dependent variable would explain between 56.5 percent and 77.4 percent of the variation in results as indicated by the diagnostics. The non significance of the goodness of fit indicates that the model fits the data well (Spicer, 2004).

Primary farm operation had positive effect on adaptation. The *t*-value of more than unity also indicated 10 percent significance of the coefficient. The mean value of 1.63 indicated the presence of more sheep farmers than cattle in the study area. Judging from the coding of the variable “primary farm operation’’, a plausible explanation of the results is that sheep farmers in the area are able to adapt to climate change more than cattle farmers.

Access to extension services was positively related to climate change. Among the exogenous variables, it was the only variable that had the highest weighting coefficient. The results indicated that having access to extension services increased the likelihood of farmers’ adaptation to climate change. Nhemachena and Hassan (2007) also discovered that access to extension services was one of the important determinants of farm-level adaptation. Total size of farm area also had positive effect on climate change but the likelihood of farmers’ adaptation to climate change varied by only 0.8 percent. Total number of people in household was also positively related to climate change and adaptation but the coefficient was not statistically significant even at the 10 percent level of significance. The results implied that large family sizes increased awareness and use of climate change and adaptation (Deressa *et. al.*, 2005).

Table 5.1: Perceptions of cattle and sheep farmers on climate change and adaptation

Variable	Mean	Std. Dev.	Variance
Adaptation Yes = 1; No = 0	0.43	0.496	0.246
Primary farm operation Cattle =1; Sheep =2	1.63	0.483	0.233
Access to extension services Yes = 1; No = 0	0.25	0.435	0.189
Total size of farming area (ha)	78.81	250.91	62957.02
Total number of people in household	6.05	3.22	10.39
Age group (yrs) 1= 16-25; 2= 26-35 3= 36-45; 4= 46-55 5= >56	3.59	0.992	0.984
Gender Male = 1; Female = 2	1.28	0.450	0.203
Non- farm income per annum (R and x 10^3) 1= 16-24; 2= 25-34 3= 35-49; 4= 50-64 5= >65	4.70	3.19	10.20
Type of weather during 2005-2009 1= Drought; 2= Wind	1.84	0.371	0.137
Temperature during 2005 – 2009 1=Increased; 2=Decreased 3=Stayed the same	2.39	0.591	0.349
Livestock production and ownership 1=Increased; 2=Decreased 3=Numbers stayed the same 4= n/a	3.79	0.683	0.466
Access to credit 1=Yes; 2=No	1.38	0.487	0.237
Access to information on climate 1=Yes; 2=No	1.80	0.400	0.160
Years of education (yrs)	1.62	0.977	0.954
Distance to weather station (Km)	26.56	28.91	835.91
Distance to input market (Km)	24.06	23.00	529.27
Barriers to adaptation 1= Lack of information; 2= Lack of credit 3= Shortage of labour; 4= Land tenure system 5= Poor grazing land	1.35	1.690	2.857
Adaptation strategies 1= Planted supplementary feed; 2= Plant windbreaks 3= Sold livestock; 4= Different livestock species; 5= Vaccination 6= Culling; 7= Migration; 8= Changed to mixed farming	7.16	5.95	35.34
Temperature ^{0}C (annual average 2005-2009)	12.66	9.01	81.26
District dummy 1= Amatole; 2=Chris Hani; 3= OR Tambo	1.62	1.262	1.594

Sample size = 500

Table 5.2: Parameter estimates of the binary logistic model of climate change and adaptation

Variable	β	Std Err	Wald	df	Sig	Exp (β)
Primary farm operation	2.583	1.573	2.696	1	0.101	13.237
Access to extension services	34.887	2769.280	0.000	1	0.990	1.417E15
Total size of farming area (ha)	0.008	0.004	3.386	1	0.660	1.008
Total number of people in household	0.044	0.107	0.169	1	0.681	1.045
Age group (yrs)	-0.142	0.408	0.122	1	0.727	0.867
Gender	-0.372	0.835	0.199	1	0.656	0.689
Non- farm income per annum (R and x 10^3)	-0.559	0.237	5.578	1	0.018	0.572
Type of weather during 2005-2009	-3.418	1.928	3.143	1	0.076	0.033
Temperature during 2005 – 2009	-2.083	1.354	2.367	1	0.124	0.125
Livestock production and ownership	1.350	0.781	2.987	1	0.084	3.857
Access to credit	1.541	1.267	1.479	1	0.224	4.670
Access to information	-2.023	2.013	1.010	1	0.315	0.132
Years of education	-0.774	0.584	1.754	1	0.185	0.461
Distance to weather station (Km)	-0.088	0.032	7.535	1	0.006	0.916
Distance to input market (Km)	0.061	0.032	3.670	1	0.055	1.063
Barriers to adaptation selections	-0.467	0.631	0.549	1	0.459	0.627
Adaptation strategies	-0.311	0.164	3.604	1	0.058	0.733
Temperature^{0}C (annual average 2005-2009)	0.168	0.095	3.141	1	0.076	1.182
District dummy	0.278	0.400	0.484	1	0.487	1.321
Constant	8.692	8.181	1.129	1	0.288	5953.741

Diagnostics:

-2 Log likelihood	= 63.279	Classification:		Goodness of fit:
Cox & Snell R square	= 0.565	No adaptation	= 85.4%	χ^2 = 1.234
Nagelkerke R Square	=0.774	Adaptation	= 90.6%	df = 1
		Overall	= 88.7%	Sig. = 0.996

N=500; Dependent variable= Adaptation ; Yes = 1; No = 0

Extensive literature indicates that households with large sizes tend to embark upon labour-intensive technology (Featherstone and Goodwin, 1993). Alternatively, research has proved that a large family is mostly inclined to divert part of its labour force into non-farm activities to generate more income and reduce consumption demands (Mano and Nhemachena, 2006). However, according to Hassan and Nhemachena (2008), the opportunity cost might be too low in most smallholder farming systems as off-farm opportunities are difficult to find in most cases. Households that had large sizes were therefore expected to have enough labour to take up adaptation measures in response to climate change (Hassan and Nhemachena, 2008). The results indicated that household size increased the probability of adapting to climate change by 4.4 percent although the coefficient was not significant.

As mentioned by Galvin *et al.* (2001), the influence of age on farmers' decision has mixed results. Some researchers have found negative relationship between age and farmers' decision to choice selection (Seo *et al.,* 2005; Sherlund *et. al.,* 2002) while others have found positive relationships (Imai, 2003; Gbetibouo and Hassan, 2005). The results suggest that the likelihood of old farmers responding to climate change and adaptation decreased by 14.2 percent.

Gender is an important variable in decision-making among farmers. Bayard *et al*. (2006) indicated that female farmers were found to be more likely to adopt natural resource management and conservation practices than their male counterparts. However, other studies showed that the variable has no significant value in decision making process (Bekele and Drake, 2003). In this study, the results of the analysis indicated a negative relationship between the decision to adapt to climate change by farmers and the likelihood decreased by 37.2 percent.

The results showed that non-farm income significantly affected adaptation choice (P<5%) and was also a strong predictor of results. Farm income represents additional wealth for livestock farmers. Higher income farmers may however be less risk-averse and have enough access to information. For this reason, non-farm income showed a negative effect on the likelihood of adaptation. The results indicated that when livestock farmers had the option for non-farm incomes, they could afford not to adapt to climate change.

Type of weather and the resulting temperature observed during 2005 and 2009 appeared to be negatively correlated to climate change and adaptation. This variable also had significant effect on adaptation ($P<10\%$) and a relatively high predictor among the independent variables. Households with windy and higher temperatures over the survey period were less likely to adapt to climate change through adoption of different practices. Furthermore, households who perceived great differences in seasonal temperatures during the survey period were less likely to adapt to climate change. Empirical studies on the impact of climate change on agriculture indicate that climate attributes significantly affect net farm income and reduce adaptation (Mano and Nhemachena, 2006).

As expected, livestock production and ownership positively affected climate change and adaptation with high marginal impact. The variable also had significant effect on adaptation ($P<10\%$). Livestock ownership plays a major role as a store of wealth in the households and also provides traction and manure required for grazing maintenance. Thus, in this study, the variable was hypothesised to have an increase in the likelihood of climate change and adaptation of farmers (Smith *et al*., 2001).

Access to credit had a positive impact on climate change and adaptation. Having access to credit increased the likelihood of adaptation by farmers (Nhemachena and Hassan 2007). The results implied that institutional support in terms of the provision of credit was an important factor in promoting adaptation options to reduce the negative effects of climate change (Deressa *et al*., 2009). Several studies have shown that access to credit by farmers is an important determinant of the adoption of various technologies (Kandlinkar and Risbey, 2000).

Access to credit has been found to assist farmers to pay for information on agriculture. In this study, such farmers were assumed to have been able to make comparative decisions on climate change and adaptation. Availability of financial resources would enable farmers to buy new breeds of livestock and other important inputs that they might require for the adaptation choices. The results suggest that access to information and years of education had negative impacts on famers' likelihood to adapt to climate change. Education has been found to be negatively correlated with farmers' decisions on climate change and adaptation measures (Gould *et al.,* 1989) while access to information has been found to have mixed impacts on the decision-making of farmers (Dolisca *et al.,* 2006).

Distance to weather station had a negative but significant ($P<1\%$) impact on adaptation. The results from this study indicate that long distances decreased the likelihood of adaptation by 8.8 percent. Distance to input markets was positively and significantly ($P< 10\%$) related to adaptation choices. Market access has been found to be an important factor in determining technology adoption choices among farmers (Luseno *et al.*, 2003). Access to input markets allow farmers to acquire inputs needed for adaptation choices such as planting of supplementary feed, windbreaks, purchase of new livestock species, vaccination etc. Zhang and Flick (2001) however, found that long distances to input markets decreased the likelihood of adaptation.

The presence of barriers to adaptation had negative impact on adaptation. Choice of adaptation strategies had negative and significant ($P<10\%$) effect on adaptation indicating that households with proper choices of adaptation strategies needed not to adapt to climate changes. Farmers who perceived higher annual mean temperatures over the survey period were more likely to adapt to climate change. The variable was also a significant ($P<10\%$) determinant of the likelihood of adaptation. The results showed that a rise in temperature one degree Celsius higher than the mean increased the likelihood of adaptation by 16.8 percent. The results indicated that with more warming, farmers would employ various adaptation measures to compensate for the loss of water associated with increased temperatures (Deressa *et al.,* 2009). Empirical studies on climate change and adaptation of farmers in Africa have shown that climate attributes in different agricultural zones significantly affected adaptation (Kurukulasuriya and Mendelsohn, 2006). Regional studies have also shown that the choice of livestock species is sensitive to climate changes (Seo *et al.,* 2005).

5.6 Conclusion

This chapter examined cattle and sheep (livestock) farmers' decision to adapt to climate change in three district municipalities of the Eastern Cape province of South Africa. The main objective was to investigate the factors that affected adaptation by small-scale livestock farmers who kept cattle and sheep. The study was based on a cross-sectional household survey data collected from 500 household heads during the 2005-2009 farming season. The BLRM was used to determine cattle and sheep (livestock) farmers' decision to adapt or not to climate change.

The results indicated that primary farm operation had a positive effect on adaptation decision. A plausible conclusion of the results was that the predominant sheep farmers in the area were able to adapt to climate change more than cattle farmers. Access to extension services was positively related to climate change and had the highest weighting coefficient. From the results, it was concluded that having access to extension services increased the likelihood of adaptation to climate change. Total size of farm area also had positive effect on climate change but the likelihood of farmers' adaptation to climate change varied by only 0.8 percent. Total number of people in household was positively related to climate change and adaptation, and the coefficient was not statistically significant. The results implied that large family sizes increased awareness of climate change and adaptation.

From the results of the study, it was concluded that household size increased the probability of farmers adapting to climate change. The results suggested that the likelihood of old farmers responding to climate change and adaptation decreased by 14.2 percent. The results of the analysis indicated a negative relationship between gender and the decision to adapt to climate change by farmers and the likelihood decreased by 37.2 percent. The conclusion was that when livestock farmers had the option for non-farm incomes, they could afford not to adapt to climate change.

Type of weather and nature of temperature observed during the study period appeared to be negatively correlated with adaptation. This variable also had significant effect on adoption ($P<10\%$) and a relatively high predictor among the independent variables. It was concluded that households that experienced windy and higher temperatures over the survey period, were less likely to adapt to climate change through adoption of different practices. Furthermore, households that perceived great differences in seasonal temperatures during the survey period were less likely to adapt to climate change.

Livestock production and ownership positively affected adaptation with high marginal impact. The variable also had significant effect on adaptation ($P<10\%$). Access to credit had a positive impact on climate change and adaptation. The results implied that institutional support in terms of the provision of credit was an important factor in promoting adaptation options to reduce the negative effects of climate change. Access to information and years of education had negative impacts on famers' likelihood to adapt to climate change.

Distance to weather station had a negative but significant (P<1%) impact on adaptation. The results indicated that long distances decreased the likelihood of adaptation. Distance to input markets was also positively and significantly (P< 10%) related to adaptation choices. The presence of barriers to adaptation had negative impact on adaptation. Choice of adaptation strategies had negative and significant (P<10%) effect on adaptation indicating that households with proper choices of adaptation strategies needed not to adapt to climate change. Farmers, who perceived higher annual mean temperatures over the survey period, were more likely to adapt to climate change. The variable was also a significant determinant of the likelihood of adaptation. The results showed that a rise in temperature one degree Celsius higher than the mean increased the likelihood of adaptation by 16.8 percent. The results indicated that with more warming, farmers would employ various adaptation measures to compensate for the loss of water associated with increased temperatures.

CHAPTER 6

CLIMATE CHANGE AWARENESS AND DECISION ON ADAPTATION MEASURES BY LIVESTOCK FARMERS

The livestock sector is a major player, responsible for 18 % of greenhouse gas emissions measured in CO_2 equivalent. This is a higher share than transport." FAO (2006)

6.1 Introduction

Awareness of climate change in many studies has been of great concern. Adaptation measures to climate change have often been a way to pursue for many African countries, in order to reduce the negative effects of climate change. A consensus has emerged that developing countries are more vulnerable to climate change than developed countries because of the predominance of agriculture in their economies and scarcity of capital for adaptation measures (Fischer *et al*., 2005). South Africa, being a developing country with agriculture dominating other sectors of the economy, is most likely to be vulnerable to climate change (Gbetibouo and Hassan, 2005). Predictions about climate change in South Africa in a study conducted in 2002 indicated that certain species of animals were likely to become extinct as a result of climate change (Turpie *et al*., 2002). The Eastern Cape province whose economy is mainly agricultural is also most likely to be vulnerable to climate change. This has necessitated this study that seeks to establish whether livestock farmers in the Eastern Cape were aware of climate change and the adaptation measures they opted for in order to curb the negative effects of climate change between 2005 and 2009.

6.2 Objectives

The objectives of this chapter was firstly, to investigate the extent of awareness of climate change in the area of study and to select livestock producers that were aware of climate change from a pool of 250 respondents. Secondly, the objective was to isolate those livestock farmers that adapted to climate change from the group that was aware of climate change, and to identify adaptation measures that they adopted. The rest of the chapter is organised as follows: In section 6.3 hypotheses is provided. In section 6.4, the empirical model that was employed is specified. Section 6.5 presents results in the form of descriptive statistics followed by Heckman's two step probit model results. Section 6.6 discusses the results and section 6.7 provides conclusion to the chapter.

6.3 Hypotheses

The following hypotheses were tested:

(i) Farmers who were aware but did not adapt compared with those who were aware and adapted to climate change would choose different degrees of adaptation measures;

(ii) The most significant factors that affected climate change and adaptation would be the gender of the livestock farmer, marital status, education, formal extension, information on climate change, average annual temperatures, and the way in which land for farming was acquired by the farmer.

6.4 Empirical model

The awareness of livestock farmers about climate change and the decision to select adaptation measures was considered to be a two-stage process. The first stage was whether livestock farmers were aware of climate change or not. The second stage involved whether livestock farmers adapted to climate change after being aware and selecting some adaptation measures. The second stage, called the "outcome" stage, was considered a sub-sample of the first stage, the "selection" stage. Since the outcome stage was a sub-sample of the selection stage, it was likely that the outcome stage sub-sample will be non-random and different from those farmers who did not become aware of climate change in the full sample. A sample selection bias was then created which was corrected by the maximum likelihood *Heckman's two-step* or *Heckit* selection procedure (Heckman, 1979).

The Heckman two-step estimation is a way of estimating treatment effects when the treated sample is self-selected. The application of this model in this study was to estimate the determinants of an individual livestock farmer's decision to select adaptation. The first step was to create a model of farmers who were aware of climate change, and then given that model, the outcomes (adaptation) was modelled (Deressa *et. al.,* 2009).

Let $\prod_{ije}$ be a vector of observations of the size of issue for the i^{th} group of livestock farmers with a j^{th} form of awareness and non-awareness of climate change, and let X_{ij} be a vector of observations on measurable socio-economic characteristics and other associated variables associated with the j^{th} state of awareness. Thus, we can specify the latent equation as:

$$\Pi^{*}_{ij} = \beta_3^{'} X_{ij} + \varepsilon_{ij} \qquad (1)$$

where $\beta_3^{'}$ is a vector of coefficients and ε_{ij} is the disturbance term in the size of the issue equation. The sample selection problem arises in the size of issue equation because the sample contains farmers that were aware of climate change and those that were not aware. Those that were aware choose between adaptation and non-adaptation.

The size of farmers who choose to adapt ($\prod_{ij}$, j=A) is observed only if the farmer was aware of climate change and chose to adapt. The size of non-adaptation farmers ($\prod_{ij}$, j=N) is observed only if the farmer was aware of climate change and chose not to adapt. These two selection processes can be considered as non-random and the model should explicitly consider this selection in order to produce unbiased estimates. To address the multiple sample selection problems inherent in the size of the adaptation equation, the following model was specified:

Let Y^*_{i1} represent the propensity of a farmer being aware of climate change rather than not. Then the relationship between the observed outcome y_{1i} and the response propensity can be written as:

$$y_{i1} = \begin{cases} 0 & ....if.....Y^{*}_{i1}.. \quad .. \leq 0 \\ 1 & ....if.....Y^{*}_{i1}.... \quad . \geq 0 \end{cases} \qquad \text{Awareness selection} \qquad (2)$$

Let y_{2i} be the corresponding propensity to choose adaptation measures versus non-adaptation measures as a result of awareness of climate change. This variable is only observed when $y_{1i} = 1$, i.e. y_{2i} is a choice between adaptation and non-adaptation if the farmer was aware of climate change and takes the value of 1 for adaptation and 0 for non-adaptation.

$$y_{i2} \begin{Bmatrix} 0 & ......if.....Y_{i2}^{*}... & . \leq 0 \\ 1 & ....if.....Y_{i2}^{*}... & .. \geq 0 \end{Bmatrix} \qquad \text{Adaptation selection} \qquad (3)$$

The variable $\prod_{iA}$ is only observed when $y_{1i} = 1$ and $y_{2i} = 1$ (aware and adaptation), while $\prod_{iN}$ is only observed when $y_{1i} = 1$ and $y_{2i} = 0$ (aware but not adapt).

Now consider a random sample of *N* observations. The selectivity model with bivariate probit selection equations for the farmer *i* are can be specified as:

$$y_{i1} = \beta_1^{'} X_{i1} + \mu_{i1}, y_{i1} = \begin{cases} 1 & .....if.....Y_{i1}^{*} > 0 \\ 0 & .....otherwise \end{cases} \qquad \text{Awareness equation} \qquad (4)$$

$$y_{i1} = \beta_1^{'} X_{i1} + \mu_{i2}, y_{i1} = \begin{cases} 1 & .....if.....Y_{i1}^{*} > 0 \\ 0 & ....otherwise \end{cases} \qquad \text{Adaptation equation} \qquad (5)$$

$$\Pi_{ij} = \beta_3^{'} X_{ij} + \varepsilon_{ij} \begin{cases} E(\Pi_{iA} | X_{iD}, y_2 = 1, y_1 = 1) \\ E(\Pi_{iN} | X_{iA}, y_2 = 0, y_1 = 1) \end{cases} \qquad (6)$$

Equation (4) summarises the first situation stage function between awareness and no awareness of climate change and equation (5) between adaptation and non adaptation. The two equations represent a partially observed Bivariate Probit Model (BPM). The partially observed situation in the model is due to the unobserved cases of the decision of some farmers between adaptation and non adaptation in cases, where farmers were not aware of climate change during the study period.

The conditional distribution of the error terms μ1, μ2 and ε_{ij} are distributed according to the multi-normal distribution with zero means and, for identification purposes, the variances equal to 1, i.e. $(\sigma_{\varepsilon}^2 = \sigma_{\mu 1}^2 = \sigma_{\mu 2}^2 = 1)$ and correlation coefficients $\rho_{12}, \rho_{1\varepsilon}, \rho_{2\varepsilon}$, respectively.

The multi-nomial structure of the model leads to the following variance-covariance matrix:

$$\sum = \begin{pmatrix} \sigma_1^2 & \rho_{12} & \rho_{1\varepsilon} \\ \rho_{12} & \sigma_2^2 & \rho_{2\varepsilon} \\ \rho_{1\varepsilon} & \rho_{2\varepsilon} & \sigma_{\varepsilon}^2 \end{pmatrix} \tag{7}$$

The three categories of observations are made with unconditional probabilities as follows:

$$y = \begin{cases} 1, y_{12} = 1 : \Pr ob(y_{i1} = 1, y_{i2} = 1) = \Phi_2[\beta_1' X_{i1}, \beta_2' X_{12}, \rho_{12}] \\ 1, y_{i2} = 0 : \Pr ob(y = 0, y_{i2} = 0) = \Phi_2[\beta_1' X_{i1} - \beta_2' X_{i2} - \rho_{12}] \\ 0, \quad : \Pr ob(y_{i1} = 0) \quad = \Phi[-\beta_1' X_{i1}] \end{cases} \tag{8}$$

The conditional probabilities for a generic *X* that might appear in either index function can be written as:

$$\frac{\partial \Pr ob(y_{i1} = 1, y_{i2} = 1)}{\partial X_i} = \psi_{i1}\beta_1 + \psi_{i2}\beta_2 \tag{9}$$

$$\psi_{i1} = \phi(\beta_1' X_{i1})\Phi_2\left(\frac{\beta_2' X_{i2} - \rho_{12}\beta_1' X_{i1}}{\sqrt{1-\rho_{12}^2}}\right) \tag{9a}$$

$$\psi_{i2} = \phi(\beta_2^{'} X_{i2})\Phi_2\left(\frac{\beta_1^{'} X_{i1} - \rho_{12}\beta_2^{'} X_{i2}}{\sqrt{1-\rho_{12}^2}}\right) \tag{9b}$$

Where Φ_2 the bivariate is normal cumulative distribution function, Φ is the univariate normal cumulative distribution function and ϕ is the normal distribution function.

The term β_1 is zero if X_i does not appear in X_{i1}; likewise, β_2 is zero if X_i does not appear in X_{i2}. Thus:

$$E\left(y_{i2} \middle| X_{i1}, X_{i2}, y_{i1} = 1\right) = \Pr ob\left(y_{i2} = 1 \middle| X_{i1}, X_{i2}, y_{i1} = 1\right)$$

$$= \frac{\Phi_2\left(\beta_1^{'} X_{i2}, \rho_{12}\right)}{\Phi\left(-\beta_1^{'} X_{i1}\right)} \tag{10}$$

and

$$\frac{\delta E\left(y_{i2} \middle| X_{i1}, X_{i2}, y_{i1} = 1\right)}{\delta X_i} = \frac{\psi_{i1}\beta_1 + \psi_{i2}\beta_2}{\Phi\left(-\beta_1^{'} X_{i1}\right)} - \frac{\Phi_2\left(\beta_1^{'}, \beta_2^{'} X_{i2}, \rho_{12}\right)\phi(\beta_1^{'} X_{i1})\beta_1}{\left[\Phi(-\beta_1^{'} X_{i1})\right]^2} \tag{10a}$$

According to Heckman (1979) the corresponding log-likelihood function to be maximized with respect to the parameters $\beta_1^{'}, \beta_2^{'}$ and ρ_{12} can be derived as:

$$\Omega = \sum_{y_{i1}=1, y_{i2}=1} In\Phi_2\left(\beta_1^{'} X_{i1}, \beta_2^{'} X_{i2}, \rho_{12}\right) + \sum_{y_{i1}=1, y_{i2}=0} \Phi_2\left(\beta_1^{'} X_{i1}, -\beta_2^{'} X_{i2}, \rho_{12}\right) + \sum_{y_{i1}=0} \Phi\left(-\beta_1^{'} X_{i1}\right) \tag{11}$$

A natural starting point for estimation would be an extension of Heckman's two-step estimator. In the first step, equations (4) and (5) are estimated using a BPM to obtain the two selectivity bias terms λ_{i1} and λ_{i2} (the inverse Mill's ratio); which are defined as (Greene, 2003):

$$\lambda_{i1} = \phi(\beta_1^{'} X_{i1})\left(\frac{\Phi[\beta_2^{'} X_{i2} - \beta_1^{'} X_{i1}\rho_{12}] / \sqrt{1-\rho_{12}^2}}{\Phi_2[\beta_1^{'} X_{i1}, \beta_2^{'} X_{i2}, \rho_{12}]}\right) \quad if \quad y_1 = 1 \tag{11a}$$

$$\lambda_{i2,A} = \phi(\beta_2^{'} X_{i2})\left(\frac{\Phi[\beta_1^{'} X_{i1} - \beta_2^{'} X_{i2}\rho_{12}] / \sqrt{1-\rho_{12}^2}}{\Phi_2[\beta_1^{'} X_{i1}, \beta_2^{'} X_{i2}, \rho_{12}]}\right) \quad if \quad y_2 = 1 \tag{11b}$$

$$\lambda_{i2,N} = \phi(-\beta_2^{'}X_{i2})\left(\frac{\Phi[\beta_1^{'}X_{i1} - \beta_2^{'}X_{i2}\rho_{12}]/\sqrt{1-\rho_{12}^2}}{\Phi_2[-\beta_1^{'}X_{i1}, \beta_2^{'}X_{i2}, \rho_{12}]}\right) \qquad if \quad y_2 = 0 \qquad (11c)$$

The BPM utilises the MLE method to allow the stochastic error terms to be correlated across equations. The parameter ρ_{12} estimates the correlation between the error terms of the BPM equations (4) and (5). If the MLE estimate of the correlation coefficient ρ_{12} is significant, then the BPM estimation is more efficient than that of independent Probit equations.

Finally, the sample selectivity adjusted size of issue equation can be written as:

$$E(\Pi_{iA} \middle| X_{iA}, y_2 = 1, y_1 = 1) = \beta_3^{'}X_{iA} + \gamma_1\lambda_{i1} = \gamma_2\lambda_{i2A} + \varepsilon_A^{*} \qquad (12)$$

Where $\varepsilon_A^{*} = \varepsilon_{iA} - \gamma_1\lambda_{i1} - \gamma_2\lambda_{i2,A}$ $\qquad E(\varepsilon^{*} | y_2 = 1, y_1 = 1) = 0$

$$E(\Pi_{iN} \middle| X_{iN}, y_2 = 0, y_1 = 1) = \beta_4^{'}X_{iN} + \gamma_1\lambda_{i1} = \gamma_2\lambda_{i2N} + \varepsilon_N^{*} \qquad (13)$$

Where $\varepsilon_N^{*} = \varepsilon_{iN} - \gamma_1\lambda_{i1} - \gamma_2\lambda_{i2,N}$ $\qquad E(\varepsilon^{*} | y_2 = 0, y_1 = 1) = 0$

In the second estimation stage (adaptation), the Tobit issue size equations incorporate the probability of the limit and non-limit observations from the first stage (awareness) estimation and take into account the correlation across equations. The correlation could arise because the unobservable capture might be correlated with the unobservable that influence the choice of the form of awareness (Yes or No) i.e. the correlation coefficients from equations (4) and (6) and equations (5) and (6) might not equal zero. The Heckman estimators described above are considered consistent, even though not fully efficient. To account for the possible correlation between the three error terms, the model was estimated in one step i.e. fully simultaneously using Full Information Maximum Likelihood (FIML) techniques. In contrast to the two-step procedure, such technique was considered to produce consistent and fully efficient estimates.

6.5 Results

The results are presented as descriptive statistics for awareness in Table 6.1 and descriptive statistics for decisions to adapt or not to adapt to climate change in Table 6.2. The different types of adaptation measures chosen by livestock farmers are highlighted in Table 6.3 for the livestock farmers who were aware, and those who were aware and decided to adapt. This is followed by results of Heckman probit selection model presented in Table 6.4 Table 6.1 presents data about livestock farmers' awareness of climate change. Of importance to the study, were the groups of variables with highest percentages. The results indicated that 57 percent of a total of 250 livestock farmers were more aware of climate change and 43 percent were not aware during the study period. With reference to household size group (6-10), the percentages were, aware (60.10%), not aware (53.30%). With gender, 93.70 percent represented males who were aware of climate change and 83.20 percent were males who were not aware of climate change. The age group of 51-70 years represented the group with the highest frequency. In this group, 65.80 percent were aware of climate change compared with 56.00 percent who were not aware of climate change. From the results, 90.90 percent were married people who were aware of climate change and 84.10 percent were not aware. Standard 6 level of education appeared to be the group with the highest percentage. In this group, 41.30 percent were aware compared with 42.10 percent who were not aware. Among the livestock farmers who owned 1-100 cattle and sheep, 64.50 percent were aware of climate change as opposed to 39.30 percent who were not aware. Surprisingly, 72.70 percent of farmers who had no access to formal extension services were aware of climate change and 72.90 percent were not aware.

Furthermore, from those livestock farmers who were aware of climate change, 74.80 percent indicated that they did not benefit from information about climate change in terms of livestock improvement. Among those that were not aware, 78.50 percent did not benefit. From those who were aware 55.90 percent perceived an increase in temperatures and from those who were not aware 72.00 percent perceived an increase in temperatures. From those who were aware 74.10 percent perceived a decrease in rainfall whereas 91.60 percent from those who were not aware perceived a decrease in rainfall. A high percentage of those who were aware and those who were not aware acquired land through inheritance with a frequency of 61.50 percent and 33.60 percent respectively.

Table 6.1: Descriptive statistics (Aware or not aware of climate change)
Dependent variable=Aware of climate change (dummy: takes the value of 1 if aware and 2 if not aware): N=250

Description of variables	Aware N_1=147(57%)	Not aware N_2=107 (43%)
	(%)	(%)
Size (*size*)		
1-5	18.90	29.00
6-10	60.10	53.30
11=15	19.60	17.80
16-20	1.40	
Gender *(Gen)*		
1=Male	93.70	83.20
2=Female	6.30	16.80
Age group *(Age)*		
16-25	1.40	4.70
26-35	5.60	5.60
36-45	16.80	13.10
46-55	65.80	56.00
>56	10.50	20.60
Marital status *(Mar)*		
1=Single	4.90	10.30
2=Married	90.90	84.10
4=Widowed	3.50	0.90
5=Separated	0.70	4.70
Educational status (*Educ)*		
1=Pre School	0.70	0.90
2=Standard 4	14.00	23.40
3=Std 6	41.30	42.10
4=Std 10	26.60	9.30
5=Higher	7.70	5.60
6=None	9.80	18.70
Total cattle and sheep owned: 2005-2009 *(Total)*		
1-100	64.50	39.30
101-200	21.50	47.70
201-300	4.70	7.50
301-400	5.60	2.80
401-500+	3.70	1.80
Formal extension services access *(Exten)*		
1=Yes	27.30	27.10
2=No	72.70	72.90
Information on livestock *(Infstock)*		
1=Yes	23.80	13.10
2=No	74.80	78.50
Aware of drought *(Awaredr)*		
1=Yes	100.00	100.00
2=No	00.00	00.00
Temperature perceptions *(Temps)*		
1=Increased	55.90	72.00
2=Decreased	16.10	17.80
3=Same	0.70	2.80
4=Not observed any changes	6.30	0.90
5=Unpredictable	21.00	6.50
Rains perception: 2005-2009 *(Rains)*		
1=Increased	2.10	1.90
2=Decreased	74.10	91.60
3=Same	3.50	0.90
4=Floods	0.70	0.00
5=Not observed any changes	1.40	0.00
Erratic	18.20	5.60
How acquired land *(Howacq)*		
1=Own finance	15.50	16.80
2=Bond	0.00	0.90
3= Land reform	32.20	4.70
6=Inheritance	61.50	33.60
7=Not applicable	38.50	43.90

Similarly, Table 6.2 presents descriptive statistics of livestock farmers who were aware of climate change and decided to select some adaptation measures. Among 143 livestock farmers who were aware of climate change, 71 percent selected some adaption measures as presented in Table 6.2, and 29 percent did not. With reference to household size group (6-10), the percentages were, adapted (58.40%), did not adapt (64.30%). With regard to gender, 96.00 percent represented those male livestock farmers who adapted to climate change and 88.10 percent were those who did not. The age group of 51–70 years represented the group of livestock farmers with the highest percentage. In this group, 66.30 percent adapted and 64.30 percent did not. The results from Table 6.2 also indicated that 90.10 percent of livestock farmers were married farmers who adapted to climate change and 92.90 percent did not adapt. The group with standard 6 level of education appeared to have the highest percentage. In this group, 40.60 percent adapted compared with 42.90 percent who did not. Among those livestock farmers who owned 1-100 cattle and sheep, 64.00 percent adapted to climate change as opposed to 23.80 percent who did not adapt. Out of the total of 101 livestock farmers who adapted, 63.40 percent had no access to formal extension services while out of the total of 42 livestock farmers, 92.50 percent had access.

From livestock farmers who adapted to climate change, 69.30 percent indicated that they did not benefit from information about climate change in terms of livestock improvement, and among those who did not adapt, 88.10 percent did not benefit. From those who adapted, 50.50 percent perceived increase in temperatures compared with 69.00 percent who perceived increase in temperature but did not adapt. From those who adapted, 75.20 percent perceived a decrease in rainfall whereas 71.40 percent were those who perceived a decrease but did not adapt. A high percentage of those who adapted and those who did not adapt did not own land. The percentages were 32.70 percent and 52.40 percent respectively.

Table 6.2: Descriptive statistics (Adaptation to climate change)

Dependent variable=Adaptation to climate change (dummy: takes the value of 1 if adapted and 2 if did not adapt): N=143

Description of variables	Adapt N_1=101 (71%)	Not Adapt N_2=42 (29%)
	(%)	(%)
Size *(size)*		
1-5	17.80	21.40
6-10	58.40	64.30
11=15	22.80	11.90
16-20	1.00	2.40
Gender *(Gen)*		
1=Male	96.00	88.10
2=Female	4.00	11.90
Age group (Age)		
16-25	2.00	0.00
26-35	7.90	0.00
36-45	14.90	21.40
46-55	66.30	64.30
>56	8.90	14.30
Marital status *(Mar)*		
1=Single	6.90	0.00
2=Married	90.10	92.90
4=Widowed	3.00	4.80
5=Separated	0.00	2.40
Educational status *(Educ)*		
1=Pre School	0.00	2.40
2=Standard 4	10.90	21.40
3=Std 6	40.60	42.90
4=Std 10	29.70	19.00
5=Higher	10.90	0.00
6=None	7.90	14.30
Total cattle and sheep owned: 2005-2009 *(Total)*		
1-100	64.00	23.80
101-200	22.70	50.00
201-300	2.70	14.30
301-400	6.70	7.10
401-500+	4.00	4.80
Formal extension services access *(Exten)*		
1=Yes	36.60	4.80
2=No	63.40	92.50
Information on livestock *(Infstock)*		
1=Yes	30.70	7.10
2=No	69.30	88.10
3= Not applicable	0.00	4.80
Aware of drought *(Awaredr)*		
1=Yes	100.00	90.50
2=No	0.00	9.50
Temperature perceptions *(Temps)*		
1=Increased	50.50	69.00
2=Decreased	16.80	14.30
3=Same	4.00	14.30
4=Unpredictable	28.70	2.40
Rains perception: 2005-2009 (*Rains)*		
1=Increased	2.00	2.40
2=Decreased	75.20	71.40
3=Same	2.00	7.10
4=Floods	0.00	2.40
5=Not observed any changes	2.00	0.00
6=Erratic	18.80	16.70
How acquired land *(Howacq)*		
1=Own finance	17.80	9.50
2=Bond	0.00	0.00
3= Land reform	22.80	2.40
4=Inheritance	26.70	35.70
5=Not applicable	32.70	52.40

Table 6.3 presents percentages of adaptation measures selected by livestock farmers who were aware of climate change and those who were aware and adapted to climate change. For those livestock farmers who were only aware of climate and those who were aware and adapted, dipping and dosing were prominent adaptation measures. The percentages were 38.5 percent and 38.7 percent respectively. The least common adaptation measure was exchange of livestock for the two groups. A study by Imai (2003) indicated that livestock farmers in rural Kenya used livestock as liquid assets. Other adaptation measures were selected at different percentage levels.

Table 6.3: Adaptation measures

	Aware: Measures (N_1 = 143) %	Aware and adapt: Measures (N_2= 101) %
Supplementary feed	12.60	9.90
Dip and Dose	38.50	38.70
Feed supplement	23.80	27.70
Sell stock to buy medicine	1.40	2.00
Exchange stock	0.70	1.00
Fence camps	4.90	6.90
Portable water	2.10	3.00
No adaptation	14.70	10.90
Total	100.00	100.00

The results of the Heckman probit model are presented in Table 6.4. Results indicated that the model had good overall predictive power, as indicated by the overall 76.0 percent prediction for the selection model and 71.4 percent for the outcome model. The likelihood ratio χ^2 - test was 237.107 for selection model and 182.905 for the outcome model. The likelihood ratio χ^2 - tests were used to test the null hypothesis for each of the model that all coefficients were zero. Given the *p*-value of 0.01 for both the χ^2 -tests, the null hypothesis for each model was rejected. The results from the selection model, which predicted factors that affected awareness to climate change, indicated that marital status, level of education, formal extension, temperatures and the way in which land used for farming was acquired, significantly affected awareness of climate change. Variables that significantly affected adaptation were: gender, formal extension, information received about climate change to improve livestock production, temperatures and the way in which land was acquired.

Table 6.4: Results of the Heckman probit model

	Awareness: Selection model (N_1 = 250)		Adaptation: Outcome model (N_2= 143)	
	B	**Sig**	**B**	**Sig**
Size	-0.041	0.485	-0.20	0.760
Gen	0.687	0.241	1.536*	0.055
Age	0.006	0.966	0.133	0.387
Mar	0.922**	0.015	-0.382	0.415
Educ	-0.291*	0.030	-0.121	0.432
Total	0.000	0.539	0.000	0.616
Formal extens	3.180***	0.000	-0.794*	0.095
Infstock	-0.657	0.193	1.520***	0.004
Awaredr	0.195	0.656	0.887	0.119
Temps	-0.436***	0.001	-0.368**	0.014
Rains	-0.047	0.721	-0.110	0.525
Howacq	0.311***	0.001	0.167*	0.057
Constant	-7.580***	0.000	-3.497*	0.044
Classification:				
Yes	= 83.9%		=	84.2%
No	= 59.8%		=	52.2%
Overall	= 76.0%		=	71.4%
-2 Log likelihood	= 237.107 (df=12)		=	182.905 (df=12)
χ^2 - test	= 79.270 (P<0.01)		=	43.064 (P<0.01)

P- values are for slopes; ****P*<0.01; ** *P*<0.05 *and* **P*<0.10= Significant at 1%, 5% and 10% probability level respectively

6.6 Discussion

The significant variables in the prediction of awareness and adaptation were gender, marital status, education, formal extension, information on climate change that improved livestock production, temperatures, and also the way in which land for farming was acquired. Gender had no significant effect on awareness but on adaptation to climate change. The study showed that male farmers were more responsive to adaptation measures (Table 6.2). A similar study conducted by Bayard *et al.* (2006) discovered that male farmers were more responsive to adaptation to environmental degradation by planting alley crops in Haiti. Other similar studies conducted by Hassan and Nhemachena (2008), and Deressa *et al*. (2009) indicated that males were more responsive to adapting to climate change. Married livestock farmers were more aware (Table 6.1) and adapted to climate change (Table 6.2). The plausible reason was that the livestock farmers interviewed had families who had stayed in the area of study for a reasonable period to observe climate change.

The group with standard 6 level of education showed more awareness (Table 6.1) and adaptation (Table 6.2) to climate change. Level of education significantly but negatively affected awareness to climate change and did not have any significant effect on adaptation (Table 6.4). The results indicated that education did not have a positive contribution to awareness. Although livestock farmers in the area of study adapted to climate change, education appeared not to be the contributing factor to adaptation. Previous research (Bayard *et al.,* 2006) indicated similar results whereby education significantly but negatively affected awareness to climate change. A study by Kabubo-Mariara (2008) discovered that education was negatively correlated with adaptation to sheep and goats rearing. The reason given was that educated farmers had alternative income earning opportunities. This is in contrast to the study by Apata *et al.* (2009), which indicated that education influenced adaptation positively. Besides, the study by Deressa *et al.* (2009) and Deressa *et al*. (2010) indicated similar results that education of head of household increased the probability of adapting to climate change.

A high percentage (72.70%) in the whole sample did not receive formal extension services and information on livestock production (74.80%). Even from those who adapted to climate change, a small percentage (36.60%) received formal extension services and 30.70 percent received information about climate change. Formal extension positively and significantly affected awareness to climate change and adaptation. The more the farmers had access to extension services and information about climate change, the more they adapted to climate change (Luseno *et al*., 2003). Formal extension must have played a role in informing livestock farmers about climate change. Formal extension service by government seemed to be a good tool that could be used to increase awareness about climate change to livestock farmers in the study area. Similar research conducted by Hassan and Nhemachena (2008), Apata *et al.* (2009), Deressa *et al*. (2010), Yesuf *et al.* (2008) and Bryan *et al*. (2009) indicated that access to and use of extension services had a strong positive influence on adapting to climate change. Similar research conducted by D'Emden *et al*. (2008) indicated that extension attendance had significant effect on adoption of conservation tillage in the cropping regions of Australia. Chen *et al.* (2010) also iterated that information sharing on perception about climate change led to adaptation in China and the results proved that the farmer's perceptions were correct.

Access to information about climate change positively and significantly affected adaptation although it did not have a significant effect on awareness. The results showed that the media played an important role in informing livestock farmers about climate change as this increased the tendency of adapting to climate change (Kandlinkar and Risbey, 2000). A study by Deressa *et al.* (2009) and Yesuf *et al.* (2008) discovered that information on climate change increased adaptation. Farmers used different crop varieties to reduce risk.

A high percentage of livestock farmers (aware and not aware) were of the opinion that there was increase in temperatures during the study period (Table 6.1). Those who adapted also experienced an increase in temperatures (Table 6.2). Changes in temperatures had significant but negative effect on awareness to climate change and adaptation thereof. Changes in temperatures did not affect adaptation to climate change. On the contrary, in the study conducted by Kabubo-Mariara (2008), farmers in Kenya would reduce their livestock to reduce risks and minimise losses when temperatures increased. In addition, a study conducted by Galvin *et al.* (2004) indicated that livestock owners would move their livestock in areas with high climate variability. Hassan and Nhemachena (2008) also indicated that farmers shifted away from mono-cropping and irrigated as a way of adapting to climate change during changes in temperatures. A similar study conducted by Apata *et al.* (2009) pointed out that temperatures positively affected adaptation to climate change. Finally, livestock farmers who did not own land had high frequency of adaptation measures although it was the same group that was aware and got land through inheritance. The way in which land was acquired significantly and positively affected climate change awareness and adaptation. Both livestock farmers who were aware and those who were aware and adapted, acquired land through inheritance (Kabubo-Mariana, 2005).

6.7 Conclusion

This chapter investigated the extent of awareness of climate change by cattle and sheep farmers in the Eastern Cape province of South Africa. It further explored adaptation measures that they followed and factors that affected adaption measures. The study was based on a cross-sectional household survey data collected from a pool of 250 respondents during the 2005-2009 farming season. The Heckman's two step model was used to determine factors that affected awareness and adaptation of livestock farmers to climate change.

The results from the selection model, which predicted factors that affected awareness to climate change, indicated that marital status, formal extension and the way in which land used for farming was acquired, significantly affected awareness of climate change. Level of education and temperatures affected awareness significantly but negatively. The results from the adaptation model indicated that the variables that significantly affected adaptation were: gender, information received about climate change to improve livestock production, and the way in which land was acquired. Formal extension and temperatures significantly affected adaptation but negatively.

The fact that the way in which land that was acquired was positive and significant in both selection and adaptation models, indicated its effective role in creating awareness and adaptation to climate change. Gender which positively and significantly affected adaptation, suggested selection of adaptation strategies depends on males possibly because they are the ones who made decisions in the household farming activities. Finally, information on climate change to improve livestock production appeared to play a significant role in the selection of adaptation measures. This calls for timely and relevant information on climate change to be made available to livestock farmers.

CHAPTER 7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

The study was intended to contribute to the body of knowledge about climate change effects together with adaptation measures pursued by cattle and sheep farmers. The study was conducted in the Eastern Cape focussing on the small-scale farmers. The first objective was to examine perceptions of cattle and sheep farmers on climate change and adaptation. The second objective was to investigate factors that affected their choices of adaptation. The last objective was to establish the extent of awareness of climate change in the area of study together with adaptation measures that were adopted. The objectives are outlined in chapter 1.

In order to accomplish the objectives, the study made use of literature review on climate change and adaptation at global scale i.e. (internationally), in Africa, and in South Africa in order to determine the effects of climate change on agriculture. The literature also focused on the impact of climate change on the livestock sector. The contribution of livestock to climate change was also covered. Challenges for poverty alleviation were discussed. Literature about perceptions on climate change and adaptation measures together with adaptation challenges was reviewed. The literature revealed that indeed climate change exists and has undesirable effects on livestock production. The study made an analysis of perceptions of cattle and sheep farmers on climate change, extent of awareness, and adaptation measures that were adopted. Challenges to adaptation were also discussed in the literature on adaptation challenges. The MDGs threatened by weather related-disasters and animal diseases, induced by climate change were also discussed. This final chapter is aimed at discussing the major findings in the form of a summary, conclusion and recommendations.

7.2 Summary

One fundamental question of interest to this research was how cattle and sheep farming in the Eastern Cape was affected by climate change, and what adaptation measures were employed by the farmers. This study used statistical methods and empirical models to:

(i) Examine the perceptions of cattle and sheep farmers on climate change and adaptation in three district municipalities of the Eastern Cape province of South Africa;

(ii) Investigate the factors that affected the choices of adaptation by small-scale livestock farmers who kept cattle and sheep; and

(iii) Investigate the extent of awareness of climate change by cattle and sheep farmers, and choices of adaptation measures that were employed, together with factors that affected adaption measures.

The outcomes of this research can therefore be summarised according to perceptions on climate change by cattle and sheep farmers, the farmers' adaptation measures, and their extent of awareness about climate change, together with factors that affected adaptation measures.

7.2.1 Perceptions on climate change

In chapter 4, the different perceptions on climate change were grouped into: (i) drought and windy weather patterns; (ii) information and adaptation; (iii) climate change and extension services; (iv) cattle and sheep production; and (v) temperature. These different perceptions proved that cattle and sheep farmers in the area of study had different perceptions on climate change. Literature review on studies conducted across the globe, to examine perceptions of livestock farmers on climate change, also indicated that farmers perceived drought and windy weather patterns as contributing to climate change. Studies also showed that livestock farmers perceived changes in temperatures in Tanzania (Mary and Majule, 2009). Findings from various studies were that climate change has proven to be existent across the globe. Some studies identified storms and occasional excess rainfall to delay planting season while others perceived unusual increases in temperatures to also delay planting season. Other studies perceived climate change to have occurred over the years due to diverse human activities (O'Brien *et al.*, 2006; Ishaya and Abaje, 2008; IPCC, 2007). The literature review indicated that in some African countries, farmers attributed the unusual weather patterns to the act of God who was angry with the sins of human beings (Patwal, 2010). Although farmers were aware of climate change, majority of them lacked detailed information about climate change. The study revealed that livestock farmers were not informed about the concept of climate change although they had observed a decline in the number of cattle and sheep in the study area during the period 2005 to 2009. This study suggests that climate change is perceived to be existent by livestock farmers in the Eastern Cape although most of them were not informed formally or otherwise.

7.2.2 Climate change and adaptation measures by cattle and sheep farmers to climate change

Chapter 5 of this study revealed that significant factors that affected climate change and adaptation were non-farm income, type of weather perceived during the period 2005 and 2009, livestock production and ownership, distance to weather stations, distance to input markets, adaptation strategies and annual average temperature. Positive and significant factors that affected climate change and adaptation were livestock production and ownership, distance to input markets and annual average temperatures over the survey period. Negative and significant factors that affected adaptation were non-farm income, type of weather perceived, distance to weather stations and adaptation strategies. These significant variables were the most important variables that prompted cattle and sheep farmers to adapt or not to adapt to climate change. Similar studies conducted internationally by FAO (2009), Anderson and Bausch (2009) and in African countries by Hassan (2010), agreed to the findings that high temperatures were brought about by climate change.

7.2.3 Awareness and decision on adaptation measures

The chapter 6 results from the selection model, which predicted factors that affected awareness to climate change, indicated that marital status, level of education, formal extension, temperatures and the way in which land used for farming was acquired, significantly affected awareness of climate change. The results also showed that marital status, level of education, formal extension, temperatures and the way in which land used for farming was acquired were the most important variables that influenced awareness about climate change among the cattle and sheep farmers in the study area of the Eastern Cape.

In terms of marital status, married cattle and sheep farmers were more aware of climate change than those that were not married. Being married had positive and significant impact on climate change awareness. Although level of education was significant, it did not positively affect awareness on climate change. The reason could be that the level of education of the farmers in the area of study was not high enough to influence awareness. In this study, the lower the level of education the higher the chances of not being aware of climate change. Formal extension increased awareness of cattle and sheep farmers on climate change. Although among farmers that were aware, only 27.30 percent received formal extension, formal extension seemed to be significant in increasing awareness to climate change.

Occurrence of high temperatures was significant but did not positively affect awareness on climate change. Cattle and sheep farmers indicated that they were aware of an increase in temperatures but that did not significantly affect their awareness on climate change. The way in which land to farm cattle and sheep was acquired, positively affected awareness on climate change. According to Table 6.1 of chapter 6, the highest percentage (61.50%) of cattle and sheep farmers that were aware indicated that they had acquired the land through inheritance, an indication that inheritance played an important role in awareness on climate change.

From the adaptation model, the results indicated that the variables that significantly affected adaptation were gender, formal extension, information received about climate change to improve livestock production, temperatures and the way in which land was acquired. The results implied that gender, formal extension, information received about climate change to improve livestock production, temperatures and the way in which land was acquired were the most important variables that influenced decisions to adapt or not to adapt to climate change. In the area of study, a high percentage (96%) of farmers who adapted to climate change was male farmers.

Male responsiveness was also observed by Bayard *et al*. (2007) when he indicated that male farmers were found to be more likely to adapt to climate change than their female counterparts. Evidence from Ethiopia cited by Deressa *et al.* (2009) also alluded to the fact that male farmers were more responsive to climate change than female farmers. However, Nassif (2008) discovered that female farmers in Morocco were the ones that adapted to climate change by allowing the development and consolidation of new practices in dealing with climate change. The female farmers had an increasing role of women in livestock production as the sector was becoming more intensive. This observation implies that adaptation to climate change is gender-responsive depending on the area of study.

This study does not support the argument that availability of extension services increases decisions to adapt to climate change, hence adaptation decisions among the cattle and sheep farmers of the Eastern Cape area of study were not influenced by the availability of formal extension services. Evidence of the argument can be taken from studies conducted in African countries by Hassan and Nhemachena (2008), Bryan *et al*. (2009), Deressa *et al.* (2010), Yesuf *et al*. (2008) and Apata *et al*. (2009) which indicated that access to and use of extension services had a strong positive influence on adapting to climate change. Similar research conducted by D'Emden *et al. (*2008) also indicated that extension attendance had significant effect on adoption of conservation tillage in the cropping regions of Australia. From this study, however, it can be concluded that extension services did not have a positive impact on adaptation to climate change in the area studied.

This study, nevertheless, supports the fact that access to information about climate change increases decisions to adapt to climate change. In the research carried out by Smit and Skinner (2002), information provision is one of the adaptation options in Canadian agriculture. This view is also supported by Bryan *et al.* (2009), Di Falco *et al.* (2009), and Deressa *et al*. (2009). Access to information seemed to be an important element that motivated adaptation to climate change among farmers. In the Eastern Cape area of study, information received about climate change to improve livestock production significantly affected adaptation to climate change. Although access to information is quite limited (i.e. 30.70%) in the study as indicated in Table 6.2 of chapter 6, it seems to be important in enhancing adaptation to climate change.

Temperatures have been purported to significantly affect adaptation in various studies and this study confirms that. Although various studies argue that high temperatures increased the likelihood of adapting to climate change; Kabubo-Mariara, (2008), Galvin *et al.* (2002), Hassan and Nhemachena (2008) and Apata *et al*. (2009), this has not been the case in the Eastern Cape area of study. Temperatures were perceived to have increased by a considerable number of cattle and sheep farmers but that perception did not have a positive effect on adaptation. Adaptation in the Eastern Cape seemed to be a difficult task to cattle and sheep farmers.

In this study, the way in which land was acquired greatly influenced adaptation to climate change. According to Table 6.2 of chapter 6, 26.70 percent acquired the land that they used for cattle and sheep farming through inheritance. Inheritance influenced the cattle and sheep farmers to adapt to climate change.

7.3 Conclusion

Eastern Cape's economy is dependent mainly on agriculture. Climate change vastly affects livestock production and impacts negatively on household economies. The province has been adversely affected by occasional droughts which have left it dry without sufficient forage for livestock production. Animal disease incidences have been reported repeatedly by several studies (Smith and Parker, 2010; Samra *et al*., 2007; Masika *et al.,* 2000). The big question is whether Eastern Cape is in a position to adapt to climate change because of its poverty levels.

Studies have been conducted to measure the impact of climate change on livestock production and adaptation in various countries across the globe. These studies have focused on perceptions of livestock farmers on climate change, adaptation measures employed and factors that affected decisions to adapt to climate change. Some of these studies have perceived that there is a change in climate and the change is mostly caused by human beings. Further studies have also revealed how livestock farmers adapted to climate change and the factors that influenced their decisions to adapt. Challenges and limitations that caused some communities not to adapt to climate change, such as lack of resources, have also been researched. In South Africa, where the study was based, climate change is a big concern. There are debates currently taking place that seek ways to deal with climate change.

South Africa is a developing country and the Eastern Cape is the second poorest province compared to the other eight provinces of South Africa in terms of per capita income, (SSA, 2003). The root cause of poverty can be linked to the apartheid era where the Native Land and Trust Act of 1936 marginalised rural areas from development initiatives. Allocation of marginal lands to rural communities led to unproductive agricultural practises. Rural areas in the Eastern Cape still show the effects of apartheid planning. As a result of poor planning, conservation of natural resources has been a great challenge for many years. This has led to low productivity in agriculture resulting in increased poverty. Besides poor planning, the Eastern Cape has experienced climate change which has negatively affected livestock production given that the rural communities in the Eastern Cape depend mainly on livestock production for livelihoods. This study has established that climate change negatively affected agriculture and this places the province in a position where climate change has to be treated as a matter of urgency.

A study conducted by the National Climate Change Response Strategy revealed that public awareness and education about climate change were lagging behind in South Africa. This can be attributed to the country's history of isolation from the international community (Madzwamuse, 2010). The study found out that the Eastern Cape province remained more vulnerable to climate change than the other eight provinces of South Africa. The study therefore, prepared vulnerable communities to be adaptable to climate change.

This study revealed that a significant number of the farmers in the Eastern Cape perceived an increase in temperatures together with a decline in rainfall. The perceptions on climate change were grouped into drought and windy weather patterns; information and adaptation; climate change and extension services; cattle and sheep production; and temperature. Livestock production and ownership, distance to input markets and annual average temperatures were the most important variables that prompted the cattle and sheep farmers to adapt to climate change. Those that did not adapt to climate change cited distance to weather stations and choice of adaptation strategies as causes for not adapting to climate change. In addition, when farmers had other sources of income, they were less likely to adapt to climate change. The factors that increased awareness about climate change and influenced decisions to adapt to climate change were married livestock farmers, formal extension, the way in which land was acquired, gender, information on climate change to improve livestock production. All these findings support the view that climate change exists and has been perceived by the cattle and sheep farmers in the Eastern Cape.

7.4 Recommendations

Cattle and sheep farmers' perceptions on climate change should be considered when programmes on cattle and sheep production are planned and implemented. Programmes should be aligned with the way in which farmers perceive climate change. This will probably help in getting co-operation from the farmers when adaptation measures have to be implemented. Cattle and sheep farmers perceived climate change in the form of drought and windy weather patterns. This implies that programmes must consider perceived drought and windy patterns.

Drought and wind management strategies and systems must be promoted strongly in the Eastern Cape. Management strategies must include adaptation activities that minimise the impact of drought and wind on cattle and sheep production systems. The role of drought in affecting fodder security and livelihoods needs to be better understood and appropriate adaptation measures must be implemented. Households with assistance from government must consider new production technologies so that they can have reserves during times of drought. National policies need to support research and development programmes that prepare appropriate technologies to help cattle and sheep farmers adapt to wind and drought. National policies also need to support research and development that prepare the appropriate technologies to help farmers adapt to climate change. The government should also consider adaptation activities that can reduce the negative impacts of wind and drought. Adaptation activities could include access of cattle and sheep to grazing reserves and to supplementary feed. Climate change also is seen and predicted to have worse impacts in the future (IPCC, 2007). It is therefore crucial to develop early warning systems that can be used to reduce disasters that can be caused by drought and wind (Zhong *et* *al.*, 2010). Early warning systems could be in the form of climate change information, including seasonal climate forecasts (Vogel and O'Brien, 2006).

In addition, a system of agricultural disaster insurance can be strengthened in the Eastern Cape to compensate for losses experienced by cattle and sheep farmers through drought and wind. A drought and wind management system could include relief activities for the welfare of those who are impoverished and who cannot afford to take disaster insurance.

In the Eastern Cape, resilience to disasters must be established. According to Zhong *et al.* (2010), resilience is the ability of a system, community, or society to adapt to fluctuation in order to maintain an acceptable level of functioning. Resilience requires social, institutional, and informational resources that enable a community to respond effectively to a hazard effect. Social resources involve social networks among community members that will help build capacity of communities to work together in adapting to climate change. Institutional resources involve governmental, non-governmental and community-based organisations. According to Tompkins and Adger (2004), community-based management enhances adaptive capacity by building networks that are important for coping with extreme events. Informational resources are all sources of information such as research stations and academic institutions. Tompkins and Adger (2003) advocated that building resilience through consolidation of social networks is useful in building resilience. All these sources can play a significant role in building resilience to drought and wind disasters in the Eastern Cape.

Further recommendation from this study is that livestock farmers should be made aware of the impacts of climate change to livestock farming through awareness programmes. The study suggests that the positive and significant variables that affected awareness in this study (i.e. married livestock farmers, formal extension, how land was acquired to farm cattle and sheep), be considered when awareness programmes are implemented. It also suggests that government awareness programmes about climate change should focus more on married livestock farmers as they were more responsive to climate change awareness. Policies that are aimed at promoting farm-level awareness need to emphasize the critical role of provision of improved formal extension together with information about climate change. This suggests that government can make use of extension services to spread the awareness message of climate change. Educational and outreach programmes on management of drought and wind should also be encouraged. Outreach programmes could be for the cattle and livestock farmers that are already farming. Educational programmes could be part of the curriculum in learning institutions.

This study recommends that communities must be consulted and involved in decision-making and testing of opinions through research. This will give a sense of ownership of natural resources which will bring about responsible use of natural resources. It will also create a sense of belonging as citizens of the country. Policy on natural resource management must include climate change as a critical element. Once natural resource management policies are implemented, they must be continuously monitored. The only challenge in implementation will be the capacity to implement. This calls for plans to incapacitate human capital with implementation and monitoring skills. As part of involvement the cattle and sheep farmers can also be part of global discourses even if it they are at local level. The discourses must speak to the global world and must not be isolated from national or international ones. Partnerships with other countries are also encouraged in this study because it is also important to learn from the experiences of other countries about climate change. Partnerships can also be encouraged as they may also influence donor-funding.

Agricultural planning must be in a position to respond to short and long-term changes in climate and vegetation. Agricultural planning must also be able to respond to changes in climate and vegetation, in particular climate change in the study area. Communities in the Eastern Cape that are the most vulnerable to climate change must be given priority during government intervention on climate change through policy-making. Livestock farmers must be fore-armed by government policies so that they can adapt to climate change without unnecessary losses to livestock production as revealed in this study.

In the Eastern Cape, the study revealed that climate change information was lacking. This study therefore recommends dissemination of information to be a critical element because livestock farmers were not informed about climate change in the study area. This study recommends that information on weather must be made available to those farmers that are far from weather stations. Extension officers who are already agents of information can be assigned to convey messages about the climate change related weather forecasts to cattle and sheep farmers in the area of study. It further suggests that appropriate information about climate change must be provided timely through the extension programmes. Provision of information can increase chances of adaptation to climate change by cattle and sheep farmers in the Eastern Cape.

The study further suggests that the positive and significant variables (i.e. livestock production and ownership, distance to input markets, distance to weather stations and annual average temperatures), which prompted the cattle and sheep farmers to adapt to climate change be considered when adaptation strategies are implemented. Adaptation to climate change is critical for cattle and sheep production to survive in the Eastern Cape. Some of the important ways to help farmers in the Eastern Cape to adapt to climate change include enhancing innovations in cattle and sheep production systems. Farmers have to learn new ways of cattle and sheep production that will enable them to reduce carbon emissions which contribute to climate change. They need to conduct livestock production practices that are environmentally friendly in order to reduce the effects of climate change. Research and development in reduction of carbon emissions should also be encouraged. This will help minimise the impacts of drought and wind disasters. These recommendations should be able to help the cattle and sheep farmers in the Eastern Cape tackle climate change impacts and farm productively, and in an environmentally friendly manner. They should also be able to help in adapting to climate change.

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APPENDIX 1

QUESTIONNAIRE

THE IMPACT OF CLIMATE CHANGE AND ADAPTATION ON CATTLE AND SHEEP FARMING IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

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

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

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

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

DISTRICT MUNICIPALITY (please tick the appropriate box):

1. Alfred Nzo	2. Amathole	3. Cacadu	4. Chris Hani	5. OR Tambo	6. Ukhahlamba

LOCAL MUNICIPALITY: ……………………………………………………………………….

WARD: ……………………………………………………………………………………………….

A.1 COMPOSITION AND CHARACTERISTICS OF HOUSEHOLD

Please fill in the household characteristics information with the interviewee.

A.1 FARM HOUSEHOLD CHARACTERISTICS

1	2	3	4	5	6	7
Size of household	Gender of head of household	Age of head of household (years)	What is marital status of the household head?	Education level	Occupation	Is farming your major source of income?
	Male……….1 Female…….2	16-25……..1 26-35……..2 36-45……..3 46-55……..4 >56............5	Single………..1 Married………2 Divorced……..3 Widowed……..4 Separated..…...5	Pre-school…….1 Std1 …………..2 Std 6. ..……......3 Standard10.……4 Higher….............5 None...………....6	Farming………….1 Employed………..2 Housewife…..........3 Pensioner………...4 Business………….5 No occupation …..6	Yes………..1 No…………2

A.2 LIVESTOCK OWNERSHIP

How many animals of each type specified below did you keep from 2005 to 2009?

Livestock	Number owned in 2005	Number looked after in 2005	Number owned in 2009	Number looked after in 2009	Total
Cattle: Cows heifers					
Bulls					
Calves					
Oxen					
Sheep: Ewes					
Rams					
Lambs					
Withers					
Total					

A.3 ACCESS TO INFORMATION ON CLIMATE CHANGE

1.1 Do you receive information on climate change?

Yes ……………………..1
No………………………2

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

1. Flyers	2. Magazi -nes	3. Radio	4. Local newspapers	5.Other (specify) ………………..	6. None	7. N/a

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?

1. Formal extension	2. Farmer to	3 Family support	4 Neighbours	5 Other (specify) ……..…………	6. N/a

	farmer				

5. What kind other support do you receive for climate change effects?

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

6. Does the information you get make any difference in stock numbers and livestock composition?

Yes ……………………..1
No……………………….2

B. LAND CHARACTERISTICS

B.1 Land tenure system

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

B. 2 Who manages the farm?

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

B. 3 Who owns the farm?

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

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

1.Own finance	2. Bond	3. LRAD	4. PLAAS	5. Restitution	6. Inheritance	7. Other (specify)……………

C. FARMERS' OBSERVATIONS ON CLIMATE CHANGE

C.1 How has the weather been in the past 5 years since 2005? Tick in the relevant box.

1. Temperatures:

1. Temperatures increased
2.Temperatures decreased
3.Temperatures stayed the same
4. Not observed any changes in temperatures
5.
6.
7.
8.
9.
10.
11.
12.

2. Rain:

1.Rains increased
2. Rains decreased
3.Rains stayed the same
4. Floods
5. Not observed any changes in rainfall
6.
7.
8.
9.
10.
11.
12.

3. Were you aware of the 2003/2004 or 2004/2005 drought?

Yes …………………….1

No……………………….2

C.2 How has the weather been since 2005 to date?

	1. Drought	2. Winds	3. Floods	4. Other (specify)
2009				
2008				
2007				
2006				
2005				

D. ADAPTATION MEASURES

D.1Did you adapt to climate change? 1. Yes…………….
2. No………………

D.2What adaptation measures have you used to deal with the changes in temperatures and rainfall?

1. Provide supplementary feed
2. Dose
3. Dip
4. Medicine
5. Dip and dose
6. Provide feed supplements
7. Provide licks, salt, dip, dose, supplementary feed, medicine, feed supplements
8. Sell stock to buy medicine
9. Exchange stock
10. Fence camps
11. Provide portable water
12. No adaptation

D.2 If you did not adapt what made you not to adopt adaptation measures?

1. Lack of information
2. Lack of money
3. Not aware of climate change
4. Do not know what to do

5. No land to plant supplementary feed
6. Distance to weather stations
7. Distance to input markets
8. Differences in agro ecological zones
9. N/A

E. CATTLE AND SHEEP PRODUCTION

E.1 Please fill in the estimated amount spent on the following activities.

2005		2009
Name of item	**Amount (R)**	**Amount (R)**
Infrastructure development/improvement (housing, warehouse, etc)		
Maintenance		
Fuel		
Labour		
Skills development		
Supplementary feeds		
Veterinary (inoculation, dosing)		
Farm equipment (purchase)		
Farm equipment (rental)		
Vehicles		
Purchase of breeding stock		
Purchase of commercial stock		
Water and electricity		
Communication		
Insurance		
Security		
Transportation of animals		
Subscription to Farmers' Association		
Sheep shearing		
Services, advice and training		
Other (specify)		

Total expenditure		

E.2 What are your major objectives of keeping these animals?

OBJECTIVES	SHEEP	CATTLE
1. Major source of income ……………………1		
2. Self-consumption ………………………….2		
3.Local status, success as a farmer, wealth…….3		
4. Lobola……………………………………..4		
3. Other (specify)……………………………..		

E.3 How many livestock did you keep (January – December).

	2005			2009		
Type of animal	**Value/animal (R)**	**Number**	**Total Value (R)**	**Value/animal (R)**	**Number**	**Total Value (R)**
Cattle: Marketable						
Small						
Sheep: Marketable						
Small						

Total Value (R)						

E.4 **What number of livestock did you sell (January – December).**

	2005			2009		
Type of animal	**Price/animal**	**Number**	**Total Price (R)**	**Price /animal (R)**	**Number**	**Total Price (R)**
Cattle: Marketable						
Small						
Sheep: Marketable						
Small						
Total Price (R)						

Thank you for answering this questionnaire

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Compliled by: B. Mandleni, University of South Africa, Johannesburg.