THE IMPACT OF CLIMATE CHANGE ON LIVESTOCK FARMING IN ESWATINI:
A MODELLING AND PARTICIPATORY APPROACH TO ADAPTATION

BY

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DECLARATION

I, the undersigned **IAN BESMAN VAN ZUYDAM** student number: **58548270** hereby declare that this thesis is my own original work with the exception of quotations and references which are attributed on their sources. This thesis has not been previously submitted to any other university and will not be presented at any other university for similar or other degree award.

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Date………16 November 2021………………………………

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DEDICATION

This thesis is dedicated to my family: Dr Nonophile Promise Nkambule, my wife; Jonathan Kian, my son; Sara-Lisa and Joni-Jonalyn, my daughters; and Mr and Ms van Zuydam, my parents. Thanks for the inspiration, support and encouragement you afforded me. May God bless and keep you all.

ABSTRACT

One of the greatest challenges faced by countries around the world, this century, is climate change. With associated evidence which includes melting ice caps, increasing land and ocean temperatures plus an increase in weather extremes such as floods and droughts, this is likely to have overwhelming impacts on most production systems including agricultural production systems including people's means to livelihoods. To ensure survival, humans have to adapt their activities. Literature indicates that, around the world and in Eswatini, in particular, research on climate change adaptation for livestock systems is limited and has many gaps. Consequently, this study aimed to investigate how climate change impacts on livestock farming in the Lowveld of Eswatini; to determine the adaptation strategies used; and investigate how access to climate forecasts influenced the farmers' adaptation strategies to climate change. To answer the research questions associated with this aim, a mixed research design was used. The primary data used for this study was collected using questionnaires from 278 sampled farmers. Other data was obtained from key informant interviews and meteorological records. The data was analysed using descriptive and inferential statistics. These results indicated that the climate of the Lowveld had significantly changed over 31 years, and this had an adverse impact on both the farmers' household and livestock farming activities. The majority of the farmers adapted both their household and livestock farming activities and used a multitude of adaptation measures. These measures were categorised into three broad adaptation strategies, namely: behavioural, management, and technological strategies resulting in a combination of eight strategies. The predictors of the farmers' adaptations were assessed using Multinomial Logistic (MNL) regression. The farmers had access to seasonal forecasts, and they used them for adapting their crop farms but not for livestock farming because these forecasts were meant for crop farming only. These forecasts only assisted the livestock farmers in adaptation planning. The country has an abundance of adaptation policies; however, they have not been operationalized into laws and regulations. Policy options to assist with adaptation include: training and capacity building, rangeland management, early warning systems, marketing, and breed diversification.

Key words: *Adaptation, Barriers, Climate change, Livestock, Perceptions, Policy, Regression, Predictors, Seasonal Forecasts, Trends,*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

Adaptation: as defined by The Intergovernmental Panel on Climate Change (IPCC) (2012a:556) is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities".

Adaptation options: is "The array of strategies and measures that are available and appropriate for addressing adaptation needs. They include a wide range of actions that can be categorized as structural, institutional, or social", IPCC, (2014c:1758).

Adaptive Capacity: is "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences", IPCC, (2014c:1758).

Maladaptation: are "actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future," IPCC", (2014c:1769).

Vulnerability: is "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt", IPCC, (2014c:1775).

Forcing: "Climate scientists define *climate forcing* as an imbalance in radiation at the top of the Earth's atmosphere. Climate forcing is the difference between the rate of energy received by absorption of solar radiation and the rate of energy emitted by the top of the Earth's atmosphere, expressed in watts per square meter (Wm^2)", (Denning, *2018: 3).*

Climate variability: "refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also Climate change", IPCC, (2014c:1761).

Eswatini: is the country formerly called Swaziland (within the country both names are used and institutions are slowly changing to carry the Eswatini name).

LIST OF ACRONYMS AND ABBREVIATIONS

CCAIRR	Climate Change Adaptation through Integrated Risk Assessment
ENSO	El Nino-Southern Oscillations
FAO	Food and Agriculture Organisation
FGDs	Focus Group Discussions
GCMs	Global Climate Models
GDP	Gross Domestic Product
GHGs	Green House Gases
GOE	Government of Eswatini
GOS	Government of Swaziland
ICARDA	International Centre for Agricultural Research in the Dry Areas
IDIs	In-Depth Interviews
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
LDCs	Least Developed Countries
MDGs	Millennium Development Goals
M-K test	Mann–Kendall Test
MNL	Multinomial Logistic (Regression)
NAPAs	National Adaptation Programs of Action
PCA	Principal Component Analysis
PHYGROW	Phytomass Growth Model
QDA	Qualitative Document Analysis
SCF	Seasonal Climate Forecasts
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
SPI	Standardised Precipitation Index
SPEI	Standardized Precipitation Evapotranspiration Index
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WSSD	World Summit on Sustainable Development

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Climate can be explained as the long-term mean variation of weather measured over number of years or decades. The earth's climatic system comprises characteristics of the lithosphere, the hydrosphere, and the atmosphere, that are all linked through the exchange of gases. Many of these characteristics are rapidly changing, and the chief drivers of these observed changes are of anthropogenic origin (Walsh *et al.,* 2014). This change has globally become known as climate change according to two global or international agencies that research and deal with climate issues, namely the United Nations - Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCC). The UNFCC (1992:3) defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods," whilst the IPCC (2014b:5) defines same as "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing's such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use."

One of the greatest challenges faced by countries around the world, this century, is climate change. Currently, climate change stands as most likely the leading global environmental challenge faced by most ecosystems and is a global challenge because it impacts every country in the world. Evidence for climate change is abundant: from the poles in melting ice caps, to the depths of the oceans (increasing sea temperature), and to the top of the highest mountains (retreating ice caps). Also evidence of climate change, put together by scientists using various weather and climate monitoring equipment and techniques – to measure and compare current and past climates, indicates that globally there is a change in climate (Walsh *et al.,* 2014). An example of evidence put forward for climate change by the IPCC (2013), for the past century, is that the earth has "warmed up," where "globally averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of 0.85 °C for the year period from1880 to 2012".

The earth's temperatures in the last 30 years have been warmer than any period since 1850. In fact the last 30 years prior to 2012 were the hottest in the Northern Hemisphere for the last 1400 years (IPCC, 2021). Whereas the latest evidence indicates that the last forty years on earth have been the warmest since 1850, while in the last decade, global average surface temperatures have increased by about 0.2°C (IPCC, 2021).

It must be noted that despite this overwhelming evidence of climate change there are some sceptics who doubt that it real; they always say, all the signs people are using as tell-tale signs of climate change are, in fact, just caused by climate variability.

Any change in climate has or will have an impact on people, communities and societies living on earth because such change impacts on their environment on which they are dependant for their livelihoods. Presently, the impacts associated with climate change are felt across many sectors that include: agriculture, fisheries, health, and water resources sector (IPCC, 2014a). In addition, these impacts increase people's and societal vulnerability, and such vulnerability is increased in developing countries, mainly in Africa, that have poor adaptive capacity (Niang *et al.,* 2014; Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN), 2011). According to Niang *et al.* (2014) Africa has low adaptive capacity because it lacks or has poor systems that can assist it to adapt, and these systems are linked to various sectors such as the economic, governance, health, educational, to name a few.

The agricultural systems in Sub-Saharan Africa are generally characterised as mixed crop-livestock systems that consist of both crop and livestock farming. The characteristic connections between these systems comprise: the use of animal draught power for land cultivation, the application of animal manure as fertilizer for cultivated crops, using crop remains as livestock feed, the generation of economic benefit from crop and livestock, and change of land use between cropland and rangelands or vice versa (Descheemaeker *et al.,* 2016). Climate change-related extremes such as increased temperature and variation in drought or flood patterns will possibly result in devastating impacts on agricultural production systems, mainly because these affect water availability, diseases, pests, floods, and droughts (IPCC, 2014a:6). This observation is further expanded by Descheemaeker *et al.* (2016), by noting that the impact of climate change in Sub-Saharan Africa on mixed farming systems will vary from place to place. Regardless of these variations, changes in climate, particularly temperatures and rainfall, will affect plant growth, thus impacting on both crops and grazing biomass. This, in turn, will affect crop yields and grazing production. Likewise, changes in grazing yields will impact on livestock systems (Descheemaeker *et al*., 2016).

For livestock systems, other direct impacts brought by increased temperatures will affect the livestock food consumption and livestock health which in turn will affect its growth and fertility leading to reduced milk and meat production (Thornton & Gerber, 2010). Porter *et al.* (2014) state that for livestock systems, temperature is a key restraining factor since it affects productivity by reducing tolerance to heat. Furthermore, livestock is affected by climate change due the impacts it has on the natural resources the livestock are dependent upon as well as the effects on livestock health; for example, through increased temperature, impacts on livestock performance, food intake and reproduction (Thornton *et al.,* 2015).

Assan (2014) concludes that in Southern Africa climate change poses a risk on the suitability of livestock farming by enhancing the pressures exerted by increased temperatures, reduced rainfall, floods or shifts in rainfall distribution that lead to reduced farming productivity. Furthermore, in sub-Saharan Africa, changes in climate will results in changes in the rangelands production and this will, in turn, impact on the amount and quality of food produced by the rangelands (Descheemaeker *et al*., 2016).

To minimize climate change threats or impacts on livestock farming, adaptation strategies must be developed and implemented by cattle farmers. Iglesias *et al.* (2012) state that an adaptation strategy is an action plan used to minimise or moderate the impacts associated with climate change. Adaptation strategies are implemented through policies, measures and instruments (Iglesias *et al.,* 2007). Biesbroek *et al.* (2013) acknowledge that such adaptation strategies are not straight forward assignments, yet they are a plan of action that could include an array of social, economic, technical, or environmental solutions. Iglesias *et al*. (2012) state that, for ease of understanding, these adaptation measures are categorised into three or four groups, namely: technical, management, infrastructural or policy measures. Silvestri *et al.* (2012) expand on these by stating that, common climate change adaptation strategies used in livestock farming include a number of facets that can either be a behavioural change such as a change in feeding; a management change that can include using different farm management methods; a technological change, such as improving the type of used livestock; or a policy change, such as new laws that can lead to adaptation.

A majority of Eswatini farmers practise mixed crop-livestock agricultural systems. In fact, agriculture supports over three-quarters of the population, and most of these persons practise subsistence farming in the rural areas of the country (Manyatsi *et al.,* 2010). The main agricultural crop grown in the rural areas is dry land maize farming (Vilane *et al.,* 2015). Of the total land area in Eswatini, grazing land occupies about 60% (Vilane *et al*., 2015; Dlamini & Dube, 2014). According to Nkondze *et al.* (2014), livestock farming contributes approximately 14% to the country's agricultural output and about 83% of the livestock is reared in communal rural areas. Livestock farming in Eswatini is a key support to the livelihoods of the rural population. The support it renders comes in many forms ranging from food (as meat and milk), fertilizer (from manure), income, draft power (mainly oxen to plough), and other classic activities associated with marriage and funerals (Ministry of Agriculture and Cooperatives, 2004; Dlamini & Huang, 2019). In addition, the entire economy of the country is dependent on agriculture. In 2011, the contribution of agriculture to GDP was 10.3% while in 2016 it was 10% (African Economic Outlook, 2018). Again, in 2018 it was 8.59% and in 2019 it was 8.77% (Plecher, 2020).

As indicated above, Eswatini is dominated by mixed agricultural systems which are not resistant to climate change shocks or impacts. However, such impacts of climate change may be aggravated by factors like: the country's dependence on dry land farming of maize, its staple food; the high population growth; water scarcity; poverty; and, as stated by scholars such as Niang *et al*. (2014), low adaptive capacity towards climate change shocks. In fact, literature indicates that throughout the year's dry land crop farming in Eswatini has been declining as a result of climate variability or change, subsequently resulting in food shortages and vulnerability (Oseni & Masarirambi, 2011). In the country, particularly the drier Lowveld where cropping systems tend to regularly fail due to climatic factors (mainly drought), the communities tend to rear livestock to sustain themselves. Hence any climate related impact on the livestock sector would have wider socio-economic ramifications and further increase people's vulnerability to poverty. As a case in point, Mhazo *et al.* (2010) and Bailey *et al.* (2019) noted that, Eswatini's agricultural system is vulnerable to the impacts of climate variability or change and related problems like drought and desertification, whilst Mushala (2003) notes that efforts to promote adaptation to climate change tend to be in competition with other national priorities like managing diseases such HIV and AIDS, or focusing on economic development to name a few.

Given the high reliance of rural communities on agriculture in Eswatini, especially livestock farming and the mentioned probable climate change impacts on such farming and the low adaptive capacity of such in sub Saharan Africa, as outlined by Niang *et al*. (2014), it is vital that a study be undertaken to evaluate the impacts and adaptation options the livestock farmers adopt as measures to adapt to the impacts of climate change in Eswatini.

1.2 Problem statement

As is widely known any change in climate has or will have an impact on people and societies living on earth because such changes impacts on their environment as well as their livelihoods (IPCC, 2014a). In addition, these impacts increase people's vulnerability, and such vulnerability is increased in developing countries, mainly in Africa, that have poor adaptive capacity (Niang *et al.,* 2014; FANRPAN, 2011). Africa's food production systems, both livestock and crops, are the world's most susceptible to climate change because of reduced productivity related to heat and drought stress; increased disease and pest damage; and climate variability and unrelenting poverty which curbs the people's ability to adapt (Niang *et al.*, 2014; IPCC, 2014b). Porter *et al.* (2014) state that despite these impacts on livestock-based farming systems, of significant concern is that, at present, there is minimal researched evidence of climate change impacts covering livestock farming with or without adaptation and their consequent impacts on human livelihoods (Porter *et al.*, 2014).

In Eswatini, the entire economy is dependent on agriculture, in 2016 the contribution of agriculture to GDP was 10% (African Economic Outlook, 2018) while in 2019 it was 8.77% (Plecher, 2020). Subsistence agriculture in the country is practiced mostly by rural households and it supports about 77% of the population. Typical subsistence farmers in the country engage in both crop cultivation and livestock rearing (Mhazo *et al.*, 2010; Dlamini & Dube, 2014; Vilane *et al.*, 2015).

Eswatini is divided into four physiographic regions namely the Highveld, Middleveld, Lowveld, and Lubombo Plateau (Thompson, 2016). The Lowveld is the hottest and driest of the other regions, but is, however, the most productive in terms of livestock production. As a case in point livestock production is the second biggest agricultural industry in the Lowveld of Eswatini to the sugarcane industry (Thompson, 2016). Droughts and water scarcity in the Lowveld are the most common limiting factors to production and these impacts are and will be exacerbated by climate change as a result of reduced rainfall and increasing temperatures as projected in the study by Manyatsi and Singwane (2013). For instance, the recent 2015 El Nino and climate change associated droughts resulted in the deaths of over 47000 head of cattle valued at R/E264 million, and most of these deaths occurred in the southern part of the Lowveld region (Swaziland Government, 2016).

A very few localised studies on climate change impacts on livestock production in Eswatini have been undertaken (e.g. Manyatsi *et al.*, 2010; Nkondze *et al.,* 2013). The study by Manyatsi *et al.* (2010) focused on mixed farming farmers' perception of climate change; whilst that by Nkondze *et al.* (2013) focused on farmers' climate change perception on livestock farming and livestock health in one of the fourteen constituencies in the Lowveld.

None of these studies focused on climate change adaptation and adaptation strategies employed by livestock farmers in Eswatini. Cooper *et al*. (2008) and IPCC (2007a) indicated that adaptation to climate change or variability enhances farmers adaptability to lasting climate change. Understanding adaptability of farmers to climate change is therefore key to sustainability of farming systems.

There is therefore a need for an in-depth study on climate change and its impacts on livestock farming, as well as the various climate change adaptation strategies used by livestock farmers in Eswatini using the lowveld region as a case study. Consequently, this study addresses the question: "What are the impacts of climate change on livestock farming and the adaptation strategies utilized by livestock farmers in Eswatini Lowveld?" Thus, this study researched the impacts of climate change in the context of livestock farming; as well as determined both present and projected climate change adaptation approaches employed by the farmers. The Lowveld of Eswatini was used as a case study because it is best suited for livestock farming yet it is the most vulnerable to the climate related impacts.

1.3 The study aim

The study aim was to investigate the impacts of climate change on livestock farming. It includes determining adaptation options currently in use, and appraising if availability of access to climate modelled forecasts or projections influence the farmers' choice of adaptation strategies. The major purpose of obtaining such information is to propose and inform future policies that could assist in developing a climate-proofed livestock industry in the Lowveld of Eswatini.

1.4 The study objectives

The study aim was realised by addressing these primary objectives:

1. To assess how livestock farming in Eswatini's Lowveld is affected by climate change.
2. To explore the climate change adaptation measures used by livestock farmers.
3. To establish if knowledge of and access to future climate forecasts and projections will influenced livestock farmers climate change adaptation strategies.
4. To propose policy guidelines that could assist livestock farmers adapt to climate change.

1.5 Research questions

The above primary objectives were achieved by answering the following primary research questions:

1. How is livestock farming in the Lowveld of Eswatini affected by climate change?
2. What climate change adaptation measures are used by livestock farmers in the Lowveld of Eswatini?
3. How does the knowledge of, and how access to available future climate forecasts would influence adaptive strategies.
4. What are proposed climate adaptation policy guidelines to assist livestock farmers adapt to climate change?

1.5.1 Hypothesis

Research Questions 1 and 2 have sub-questions (see table 4.2) that evaluate livestock farmers' perceptions of climate change, the perceived climate change impacts as well as determining the factors that predict the choice of adaptation by livestock farmers. Outlined below are the sub-questions and the associated posed hypothesis:

What are livestock farmers' perceptions of climate change and climate change impacts?

H_0: Livestock farmers' perceptions of climate change and climate change impacts are not influenced by farmers' biological characteristics.

H_1: Livestock farmers' perceptions of climate change and climate change impacts are influenced by farmers' biological characteristics

How has climate change impacted on livestock farmers at the household level?

H_0: Livestock farming in Eswatini's Lowveld is not affected by climate change.

H_1: Livestock farming in Eswatini's Lowveld is affected by climate change.

What factors determine the choice of adaptation by livestock farmers?

H_0: The livestock farmers' adaptation choices are not influenced by socio-spatial (biographical) characteristics.

H_1: The livestock farmers' adaptation choices are influenced by socio-spatial (biographical) characteristics

1.6 Justification of the study

The extreme climatic conditions, in the form of droughts, impact significantly on cattle farming in Eswatini, particularly in the dry Lowveld. The drought in 2015/16 caused by El-Nino witnessed farmers in Eswatini losing millions of Emalangeni/Rands (1 Lilangeni = 1 Rand). The Central Bank of Swaziland (2019) reported that, the entire agricultural sector shrank by 11.4% due to these droughts. Furthermore, Eswatini's livestock sector contracted by about 19% since the 2015/16 El Nino induced drought and cattle populations in 2019 are 25% lower than the pre-drought period. Over the years, increased occurrence of droughts in the Lowveld of Eswatini have seen the conversion of most crop farmers to livestock farmers, but recently these frequent droughts are also impacting livestock, and thereby affecting farmers main source of livelihoods. This situation seems to be more pronounced amongst communal small-scale farmers than commercial farmers. Considering these problems experienced by livestock farmers caused by climate variability/change, it is essential that a study, that could assist them and other key stakeholders have climate-proofed livestock industry in the Lowveld of Eswatini, be carried out.

Secondly, this study will assist in providing scientific information on climate related impacts in relation to Eswatini's livestock farming that is very limited in comparison with other farming systems, such as cropping systems (Porter *et al.*, 2014). Literature searches indicate that only a localised study on climate change and its impacts on livestock farming was carried out in a small area (Mpolonjeni area) in the Lowveld by Nkondze *et al.* (2014), and it was only limited to subsistence farmers; hence, this study does not provide comprehensive information on climate change and its impacts on livestock farming in the Lowveld region of Eswatini. This current study focuses on both subsistence and commercial livestock farmers in the Lowveld region of Eswatini. This study, therefore, builds on the findings of the study on the Mpolonjeni area (by Nkondze *et al.*, 2014) and assist in providing new and additional information on climate change and livestock farming in the Lowveld of Eswatini.

Thirdly, researchers such as Niang *et al.* (2014) identified several research gaps for climate change and adaptation studies in Africa, and such gaps include: “Determining principles or factors for effective adaptation, including community-based adaptation.” This study, therefore, will attempt to bridge this research gap.

Fourthly, this study will highlight how and why climate forecasts and projections could assist livestock farmers adapt their farming to the short and long term impacts of climate variability or change. It will be the first of its kind for livestock farming in Eswatini, and this information could greatly assist in minimising impacts related to climate variability or change. The information from this study could be used by policy makers to inform policy decisions to assist the farmers make more informed livestock farming decisions, and thus have more climate-proofed livestock farming enterprises.

Lastly, this study will assist in identifying policy gaps identified by the farmers that need to be addressed to promote effective adaptation by the livestock farmers.

1.7 Contribution of study to the body of knowledge

Baptista *et al.* (2015:55), in their study titled: “The doctorate as an original contribution to knowledge,” indicate that a doctoral contribution can consist of three related elements that can all contribute to “doctarateness these being originality, creativity and innovation”. These three features are able to contribute to a doctoral contribution in overlying yet different ways subject to the perception that “doctorateness” strikes as being a complicated theory on its own. According to Baptista *et al.* (2015), in the uniqueness of research both innovation and creativity which includes originality, there is also a likelihood that originality lacks innovation and or creativity. Conceptually, the links between these three features is displayed in Figure 1.1.

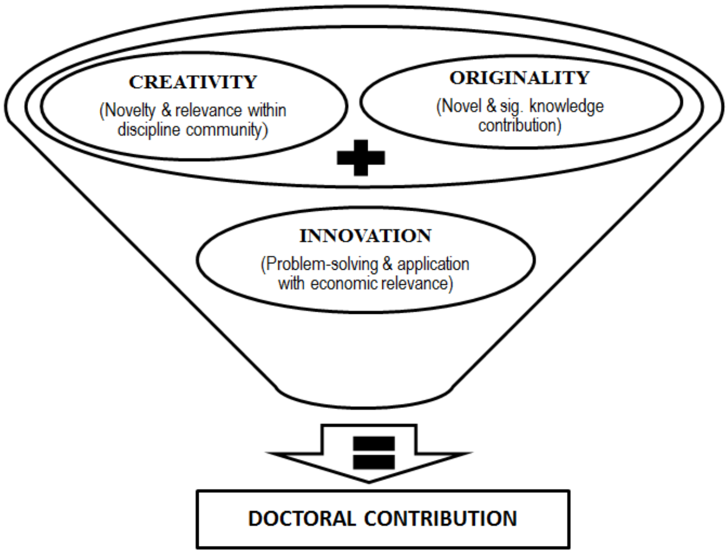


Figure 1-1: The association amongst originality, creativity and innovation.

With regard to originality, Guetzkov *et al.* (2004:190) state that there are varying definitions of originality per discipline; for example, for natural sciences originality is "the production of new findings and new theories," whereas in humanities and social sciences it is "much more broadly as: using a new approach, theory, method, or data; studying a new topic, doing research in an understudied area; or producing new findings." Creativity, in simple terms is about how creative, different, original and relevant students are in conducting their research (Bennich-Björkman, 1997; Baptista *et al.,* 2015). Lastly, innovation has grown into a requirement for doctoral research; for example, in Europe, the Lisbon Declaration on the purpose of Europe's universities (2007) associates innovation with university research in order to try and solve or address 21st century problems (Baptista *et al.,* 2015). Hence, innovation in doctoral research should provide useful knowledge for the use or betterment of society (Baptista *et al*., 2015).

In line with the above, the contribution of this study to the body of knowledge encompasses these three elements. With regard to *originality,* although the study draws on a large amount of information and studies conducted on climate change and adaptation, not much has been done in the context of Eswatini especially with regard to climate impacts on livestock farming and how farmers adapt. Furthermore, no study had been done focussing on the entire physiographic region of the Lowveld of Eswatini. Consequently, the outcomes of this study are evidently different from other studies in Eswatini, and thus are original. Given that most research in Eswatini on agricultural systems focuses on climate adaptation in crop farming and not on livestock farming, this study, therefore, fills the gap of providing empirical evidence on the topic by investigating the issues relating to climate adaptation amongst livestock farmers in the Lowveld of Eswatini.

With regard to *creativity* the study used a multifaceted approach to understand climate change, its impacts, and adaptation strategies used by the farmers in the Lowveld of Eswatini. These included: trends, perception, practices (adaptation), and policy aspects used to promote change adaptation. Included in this methodology were the predictors of the farmers' perceptions and their adaptation strategies. No such study and methodology has been employed for climate change related studies in Eswatini, but it has been used in part, in other countries. Secondly, the use of long term climate forecasts as a tool for adaptation of livestock farming, and also using future climate projections to determine adaptation options was also a creative way to determine farmers understanding of climate and how it related to present and future livestock farming activities and adaptation options. By so doing, this study contributes to knowledge in this subject as no such study has ever been conducted in Eswatini before.

Lastly, with regard to *innovation*, the study should be of societal use. In this regard it focuses on a key component of the GDP of Eswatini that relates to livestock farming. This type of farming affects about 70% of Eswatini's population; thus, by providing any deeper knowledge in this sector is beneficial to the society. This study; therefore, proposed future policy guidelines and other key recommendations which can assist livestock farmers adapt to the impacts relating to climate change. These proposed recommendations could be useful for future livestock farming in the Lowveld of Eswatini.

In conclusion, it is obvious that the study findings will provide valuable insights for the agricultural, climate, agro-climatic and policy disciplines by contributing to the body of knowledge of these disciplines, as well as how they related with climate adaptation. In addition, a contribution to the body of knowledge on the use of early warning systems, such as seasonal forecasts as tools for adaptation in livestock farming, is made. Likewise the study also contributed to literature on policies for climate change adaptation, by using both a bottom-up and top-down approaches to policy evaluation. Lastly, the study provides suggestions for policy options to be considered in climate-proofing for livestock farming in Eswatini.

1.8 Thesis Structure

The thesis is organised into the following seven chapters:

Chapter 1: **Introduction.** Outlined and discussed in this chapter are: the background information on the study; the problem being studied; the study aim; the associated research objectives; justification of the study; the contribution of the study to the body of knowledge; and thesis layout/structure.

Chapter 2: **Study area.** This section provides an account of the area of study in relation to the problem. This includes: a description of land use in Eswatini; a brief report on Eswatini's agricultural sector and livestock sub-sector; as well as the characteristics of the Lowveld region of Eswatini which is the focus of the study.

Chapter3: **Literature review.** Discussed in chapter 3 is the reviewed literature applicable to this study. It reviews literature on how climate trends are used to determine climate change. The chapter also focuses on livestock production in Eswatini and provides a review on how livestock in international countries, African countries and South Africa are affected by climate change. Also focussed on in the review is the issue of farmers vulnerability to climate change. Correspondingly looked at, is how climate change is perceived by farmers and how they adapt to it. Furthermore, an appraisal of literature on climate change adaptation policies and their evaluation is conducted. Lastly, the chapter focuses on how future climate data assists farmers' decisions on adaptation options.

Chapter 4: **Research design and methods**. This chapter outlines the methods employed to conduct the study; for example, the research design, sampling method, method of data collection, validity and reliability tests, the methods used for data analysis, and presentation.

Chapter 5: **Research findings.** This chapter presents the results namely: historical trends, future forecasts, and long-term projections. Also presented are farmers' perceptions and adaptation strategies.

Chapter 6: **Results discussion and implications.** Discussed in this chapter are the key results and findings as well as outlining the implications of the findings in the light of other studies or the theoretical literature.

Chapter 7: **Summary, Conclusions and recommendations.** Provided in this chapter are the summaries the key findings and conclusions; as well as providing recommendations that emanate from the study findings.

1.9 Chapter summary

Outlined in this chapter is the background to climate change and its impacts on livestock farming from a global to a local context. The chapter then discusses the problem statement and provides motivation for the study in the context of the Lowveld region of Eswatini. Then, subsequently described are the aim, the objectives and associated research questions, as well as justification of the study and a brief statement on how this thesis will contribute to the broader literature. Lastly, the chapter provides a chapter by chapter overview of the thesis.

CHAPTER 2

STUDY AREA

2.1 Introduction

This section provides a representation of the area studied in relation to the problem, and this includes: the description of the area's location, a report on land use in Eswatini, followed by a report on the region's climate along with a depiction of the characteristics of the Lowveld region of Eswatini which is the focus of the study. Finally, a description of the agricultural sector and the livestock sub-sector of Eswatini is presented.

2.2 The area of study

The Kingdom of Eswatini (formerly Swaziland) is found in the Eastern southern Africa bounded by latitudes 25 and 28 degrees South and 30 and 33 degrees East. The country is landlocked and covers an area of 17370km^2 (Manyatsi *et al*., 2010). Eswatini is partly surrounded by the Republic of South Africa in the north, south and west, and on its eastern border is Mozambique (see Figure 2.1). The population of Eswatini is about 1.12 million (Central Statistics Office, 2017) and about 77% of its population resides in rural areas (Ministry of Agriculture and Cooperatives, 2004: Thompson, 2016) where they practise subsistence rain fed mixed farming (Mhazo *et al*., 2010). Nkondze *et al.* (2013) approximate that about 70% of the people in the country live under the poverty threshold. This observation is echoed by the African Development Bank [ADB] (2017) report which notes that despite Eswatini's classification as a low middle-income country, around 60% of the residents' income level is under the threshold limits for poverty. Furthermore, high levels of poverty expose the people to exogenous shocks such as climate change, epidemics, droughts and diseases. With regard to shocks related to sickness and diseases, susceptibility is compounded by the fact that over 40% of the residents are HIV positive and such places a strain on the country's limited resources (Thompson, 2016). The majority of these vulnerable people reside in the Lowveld when compared to other physiographic regions.

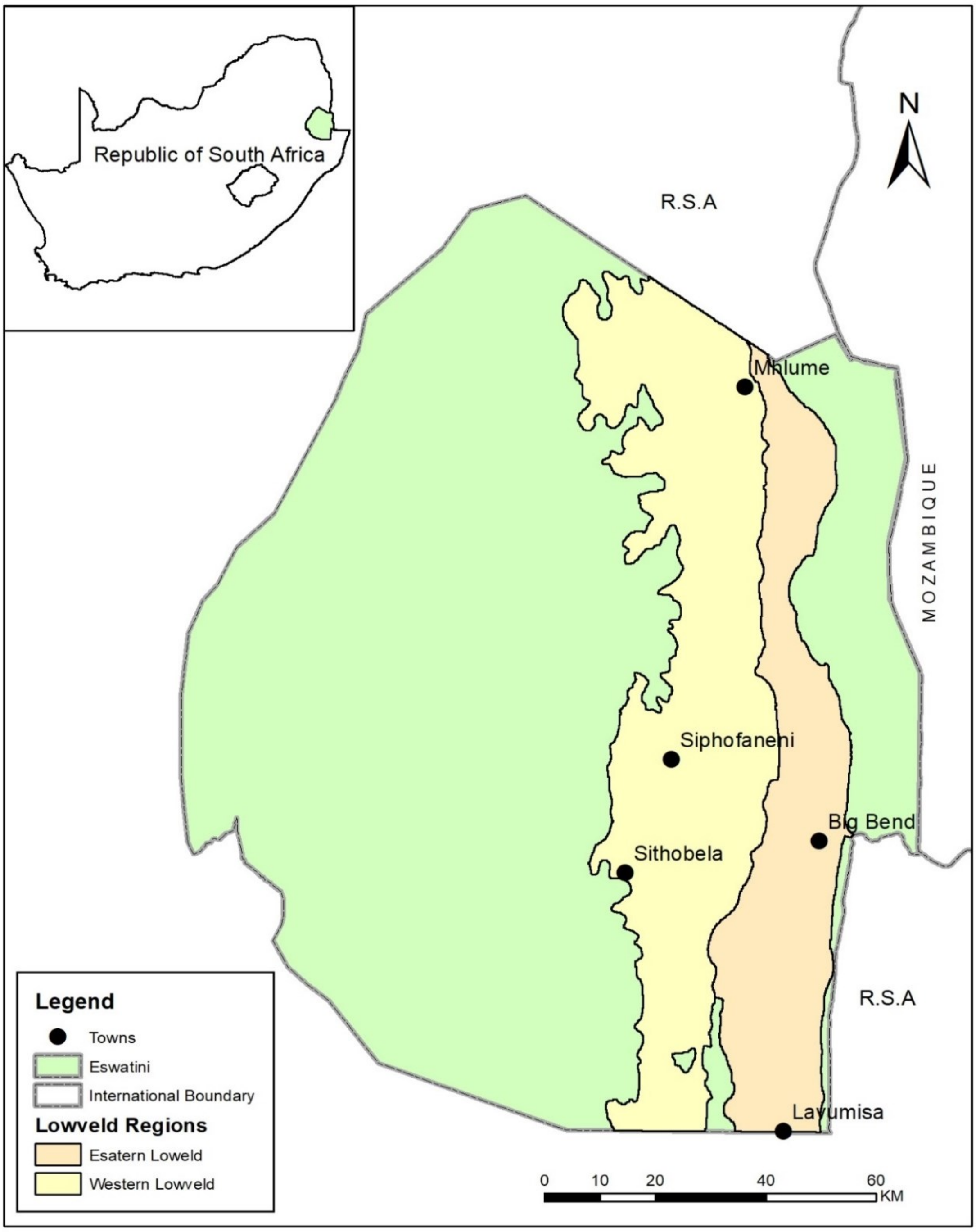


Figure 2-1: The extent of the Lowveld Physiographic zone of Eswatini.

(Source: adapted from Ministry of Agriculture and Cooperatives, 2004:3)

2.3 Characteristics of the lowveld Region

Eswatini has great climatic and physiographic variability, and thus, it is divided into four physiographic areas namely: the Highveld, Middleveld, Lowveld, and the Lubombo Plateau (Thompson, 2016). The area of interest, the Lowveld (see Figure 2-1 and 2.2) has the following characteristics as outlined in Table 2-1.

Table 2-1: Characteristics of the Lowveld of Eswatini

Zone And Area	Altitude (M)	Topography And Geology	Climate And Rainfall	Vegetation Type
Western Lowveld covering about 3 410km^2	250-400	Undulating plains with a mainly Sandstone/Clay stone underlying geology	Dry semi-arid 625-725mm	Mixed savanna
Eastern Lowveld covering about 1 960km^2	200-300	Gently undulating plains with a mainly Basalt underlying geology	Dry semi-arid 550-625mm	Acacia savanna

(Source: Adapted from the Ministry of Agriculture and Cooperatives, 2004; Sweet and Khumalo, 1994)

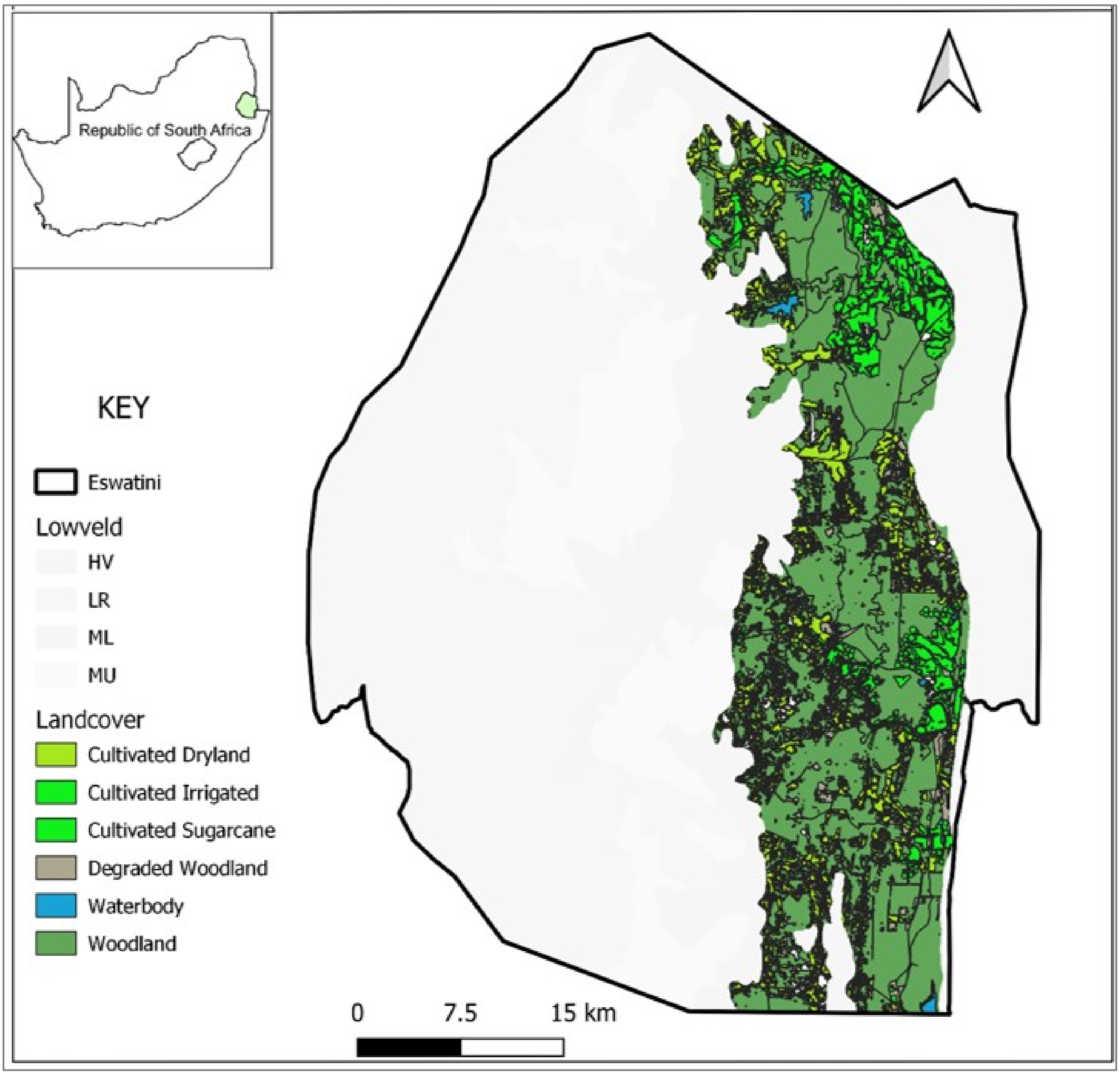


Figure 2-2: Land cover map of the lowveld

(Source: adapted from UNESWA-GEP department GIS Maps)

2.4 Climate

Generally the climate of Eswatini has the four distinct seasons with a climatic characterisation that is subtropical with summer rains. About 75% of the rain is received between October and March, and the average annual rainfall ranges from 550mm in the Lowveld to 1450mm in the Highveld, (see Figure 2.3). There is a high year-to-year variability of rainfall in the Lowveld, and thus drought conditions have always been an inherent characteristic of this semi-arid region (Ministry of Agriculture and Cooperatives, 2004). Furthermore, Manyatsi *et al*. (2010) note that Eswatini is susceptible to the occurrences of natural disasters linked to climate extremes; for example, floods that can include tropical cyclones and droughts usually associated with El Niño. The country faced its longest drought between 1989 and 1994, and the effect of this drought was very severe on cattle, where in 1992 alone, about 90,000 cattle (20% of the total herd) died in the country, while in 2015/16 the El Niño drought resulted in the loss of about 25% of the national herd (Central Bank of Swaziland, 2019). This effect was more severe in the Lowveld region, as a case in point a study by Tfwala *et al*. (2020), on the temporal variability of droughts in the Kingdom of Eswatini from 1981 to 2018, indicated that there is a spatial and temporal increase in droughts prevalence and severity, especially in the dry Lowveld, where over two thirds of the droughts occurred after 2000 for the analysed period. While floods also impact on the population, for example, the most devastating flood which affected over 400,000 people (about 40% of the population) was caused by cyclone Domonia in 1984 (Manyatsi *et al*., 2010).

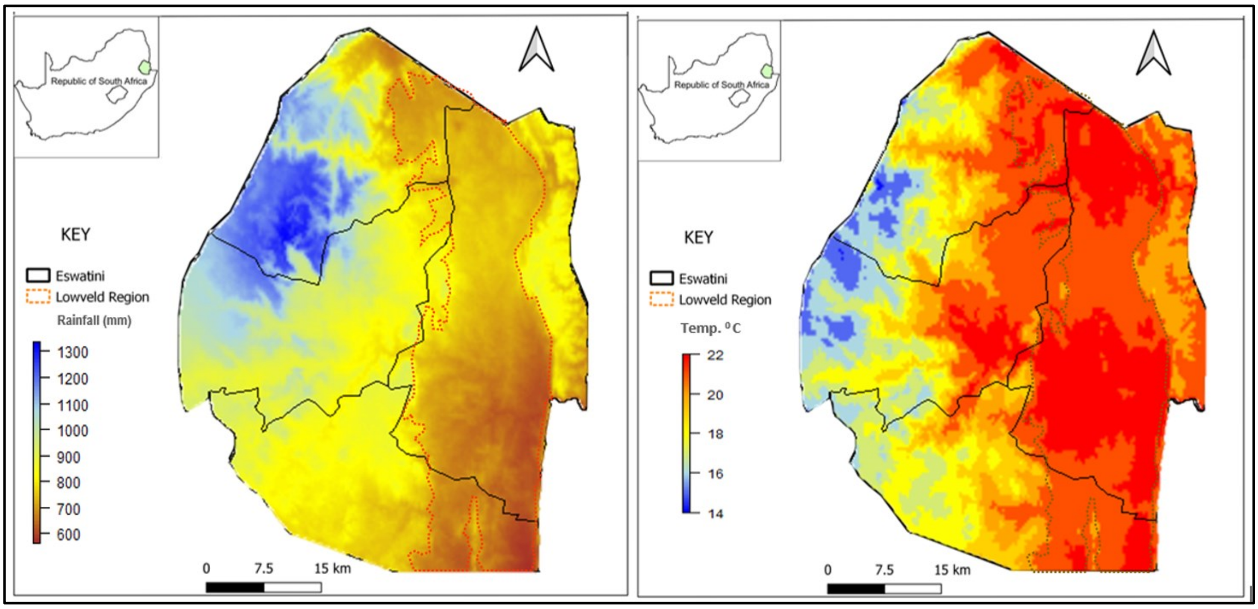


Figure 2-3: Maps indicating Isotherms (average yearly temperatures') and Isohyets for Eswatini

(Source: adapted from UNESWA-GEP department GIS Maps)

2.5 Hydrology

Eswatini is drained by six major river basins that flow generally in an eastern direction, from the north they are the Lomati, Komati, Imbuluzi, Lusuthu, Ingwavuma and the Phongola in the South. (Matondo, 2012). The lowveld region is drained by five of these rivers and their tributaries, the only river that does not drain the lowveld is the Lomati in the north, (Figure 2.4). The bulk of the river water in the lowveld is used for irrigation of crops mainly sugar cane. These rivers tend to have very high flows in summer and low base flow in winter and to ensure water for irrigation, a number of dams have been constructed to assist in water storage. These dams include the Maguga dam and Sand-River dam on the Komati, the Mnjoli dam on the Imbuluzi and the Lubhovane dam and Hendrick van Eck dam on tributaries of the Lusuthu. On the Pongola River, the Pongolapoort dam (constructed in the Republic of South Africa) has a lake that extends into Eswatini and part of the water is used for irrigation as well (Matondo, 2012).

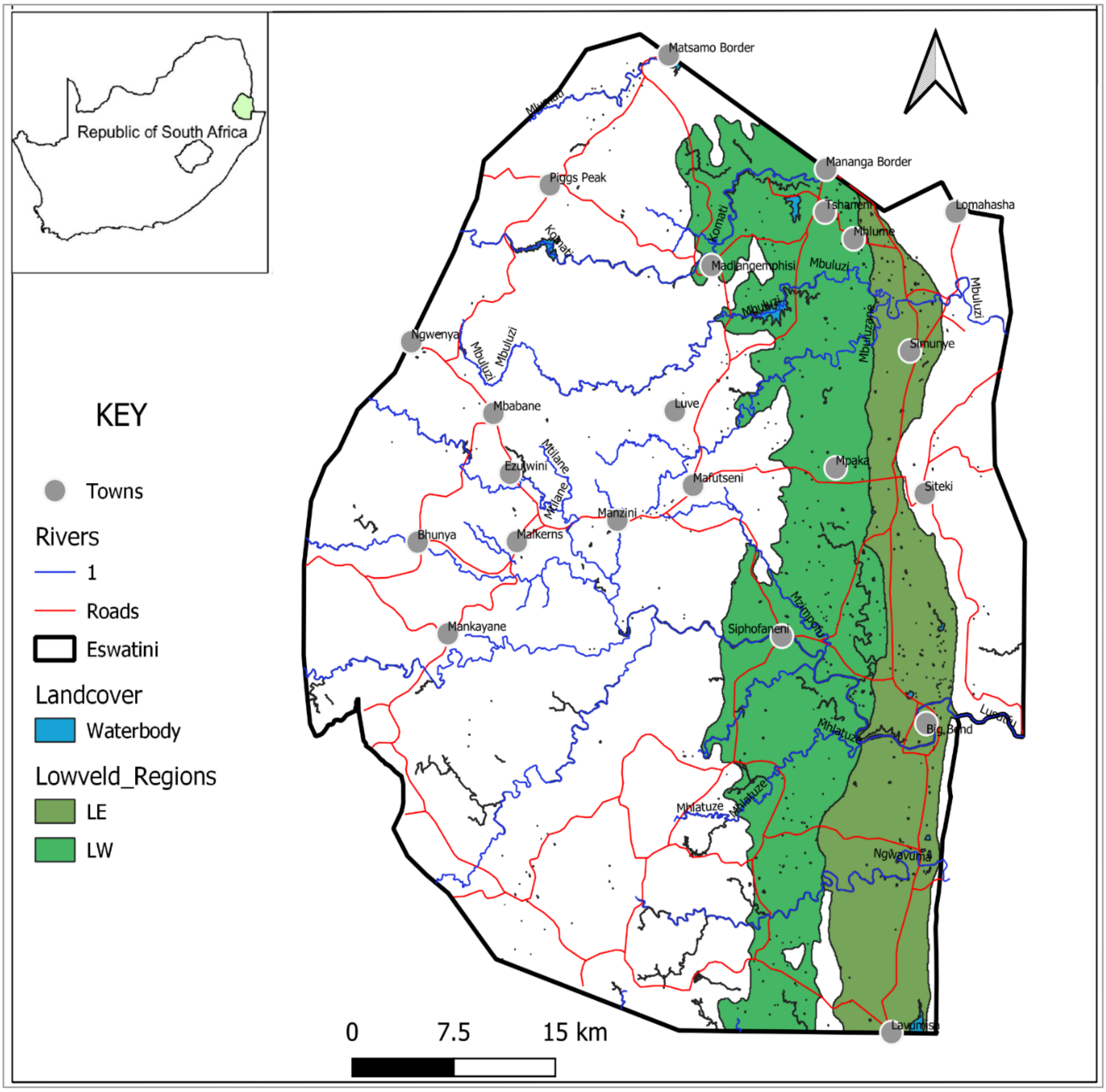


Figure 2-4: The major rivers, towns and roads in the Study area and Eswatini

(Source: adapted from UNESWA-GEP department GIS Maps)

2.6 Land use in Eswatini

Livestock grazing is the predominant land use in Eswatini, with about 67% (or 11630 km^2) of the surface area used for grazing. 83% of the country's livestock is reared extensively in communal grazing land that occupies 48% of the entire land area (Nkondze *et al*., 2014), and commercial ranching takes up 19% of the land (Sweet & Khumalo, 1994). The stocking rate is roughly 2.6 hectares per livestock unit which is among the highest in Africa; hence, this leads to degradation (Mhazo *et al*., 2010). Arable crop farming is another important land use and it covers about 18%

of the land, while plantation forestry takes 8% of the country's land surface (Ministry of Agriculture and Cooperatives, 2004; World Bank, 2011).

2.7 Agricultural sector of Eswatini

The agricultural sector is the cornerstone of Eswatini's economy (Ministry of Agriculture and Cooperatives, 2004; Thompson, 2016). 70% of the inhabitants obtain their subsistence from agriculture (Thompson, 2016), and the agrarian sector accounts for 7% of the GDP (Central Statistics Office, 2015). The dominant agricultural crops in Eswatini consist of maize, sugarcane, citrus, and, cotton; while the dominant livestock include cattle, goats, poultry and sheep. It has recently been noted that the agriculture percentage contribution to the country's GDP has been declining in recent years, and the economy is shifting to the manufacturing sector (Ministry of Agriculture and Cooperatives, 2004; World Bank, 2011; African Development Bank, 2017). The agricultural sector, including agro-based industries, is also an important foreign exchange earner accounting for about 45% of the value of national exports, thus the country's heavy reliance on the agricultural sector and agro-based industries renders the economic growth of the country vulnerable to climate change or climate induced shocks (Ministry of Agriculture and Cooperatives, 2004; African Development Bank, 2017).

The Eswatini agrarian sector can be segregated into either commercial (mainly formal) or subsistence (mainly informal) farming. Similarly the land tenure system is also divided into two namely: Title Deed Land (TDL) and Eswatini Nation Land (ENL). On TDL formal agriculture is generally practised, where the main activities include the farming of sugar cane, citrus, forestry, and mainly the rearing of cattle for beef and milk, and poultry (layers and broilers). Other commercial farming activities include vegetable farming. In the ENL tenure system, land is held as communal land where usage rights are governed by traditional laws and customs. Most agricultural activities on such communal land are carried out for subsistence purposes. The main crops grown on ENL include maize, beans, cotton, ground nuts and vegetables, while the livestock reared is dominated by cattle, goats and poultry. It must be noted that with assistance from government and other stakeholders, the informal farmers have started entering the formal agricultural sector and are mainly growing sugarcane (Thompson, 2016).

2.8 Livestock sub-sector

According to the Central Statistics Office (2015), the livestock sub-sector in Eswatini contributes about 43% of agricultural production (about 3% the country's GDP). Eswatini's subsistence livestock farming, comprising about 80% of the national livestock head that takes place on ENL, has a high prospect for the improvement of production mainly because the livestock is reared for subsistence instead of commercial purposes (Nkondze *et al*., 2014; Thompson, 2016).

Livestock in Eswatini is considered a vital asset for the sustenance of farmers, and as such, it is farmed for many reasons including: the provision of milk and meat; for social or cultural values or ceremonies such as wedding; for the production of organic fertilisers; and for draught power for ploughing their fields. The main livestock farmed in Eswatini includes chicken, cattle, goats, pigs and sheep. Other livestock raised include: donkeys, ducks, geese, turkey and horses (Nkondze *et al*., 2014). Most of the livestock farming is in the smallholder sector where the farmers' rear animals mainly for subsistence purposes, and these production systems are of low input (Dlamini & Huang, 2019). Livestock farming in Eswatini is being impacted by occasional droughts and or climate change as indicated by studies (Manyatsi *et al*., 2010, Nkondze *et al*., 2014; African Development Bank, 2017) in fact a study by Tfwala *et al*. (2020) reported that the drought of the years 2015-16 resulted in the national death of 47 000 cattle valued at E/R 264 million.

The focus of this study is on livestock, mainly cattle, goats and sheep. Cattle production comprises the largest component of the livestock sector in Eswatini by value, and cattle are the main investment asset where smallholder farmers own about 85% of the national herd (Ministry of Agriculture and Cooperatives, 2004; World Bank, 2011b; Central Bank of Swaziland, 2019). Generally, the number of cattle in the country is on the increase except during drought years where the country tends to lose a lot of animals due to farmers' reluctance to cull their livestock except when pushed by acute socio-economic conditions (Ministry of Agriculture and Cooperatives, 2004; World Bank, 2011b). As for small ruminants, goats outnumber sheep by 18:1 amongst smallholder farmers (Ministry of Agriculture, 2018). Goats are reared for multiple reasons, the main ones being social/cultural use, cash income, meat and skins; and sheep are mainly kept for cultural use and meat. The major goat and sheep breeds in the country are indigenous (Ministry of Agriculture and Cooperatives, 2004).

2.9 Conclusion

This section described the setting of the study area. It outlined the study areas' location and the physiographic/ecological zones of Eswatini with particular emphasis on the Lowveld region. This was followed by the description of the main economic activities as well as the agricultural and the livestock sector in the study area. Also, the climate of the area was described with reference to temperatures and rainfall patterns. From this, it was observed that the Lowveld of Eswatini was experiencing some form of climate change. In the following chapter, the theoretical framework of the study is described.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

Climate change dominates most environmental or socio-political discussions and such interest on this subject is increasing, as a case in point. Elmhagen *et al.* (2015) state that currently climate change represents the core topic in the worldwide environmental politics agenda. The rationale for this corresponds with indisputable changes or warming to the earth's climate resulting in unparalleled changes to the planets, biosphere, hydrosphere, cryosphere and atmosphere, and mainly as a results of mankind's unsustainable activities (IPCC, 2013 & IPCC, 2018). The abovementioned changes are projected to, furthermore, impact on both natural systems and anthropogenic systems worldwide. Temperature variations and shifts in rainfall patterns will have extensive impacts on water availability, pests and diseases, floods and perpetual droughts which all will have devastating impacts on agricultural production in Africa. Due to climate change, there is a general consensus that economically developing nations are further susceptible to climate change shocks than industrialised nations, owing to their economies dependence on agriculture and the scarcity of capital to fund climate change adaptation and their rather tropical climates (Fischer *et al.,* 2005).

In light of these noted concerns about climate induced impacts on the developing countries' economies and their inhabitants, it is true that such impacts necessitate further studying for the purpose of obtaining understanding of how best adaptation measures can be implemented across various sectors.

As the study focuses on livestock farming systems and ensuring that understanding of climate change and its induced impacts on the livestock sector is addressed, the review of literature will focus on a diverse range of facets, extending from what climate change is together with its causes and impacts in relation to the environment and agriculture, with a particular interest on livestock systems. Furthermore, focus will be on how trends are used to determine climate change. Equally important, vulnerability as a consequence of climate change will be reviewed within the context of the study. Also, the literature review will explore how climate change is perceived by farmers, and consider the climate adaptation approaches and strategies they employ, as well as policy issues associated with adaptation. Lastly, the review of literature will target the use of climate forecasts by livestock farmers for climate adaptation.

3.2 Climate change causes

In November 2015, at the COP 21 meeting in Paris, there was growing consensus that climate change is a verifiable world-wide conundrum caused by man-made actions, specifically the combustion of fossil energy sources. This observation concurs with that of the IPCC (2014a) and Walsh *et al*. (2014). The latter note that existing research brings attention to very strong evidence of a change of the world's climate systems. These changes are driven primarily by human-induced activities, and these changes will have a very large impact on natural and social systems; for example, observed changes are an increase in the total number of storms that are resulting in great destruction and losses. Furthermore, evidence of anthropogenic impacts on the earth's climate systems have grown recently. Over 50% of the witnessed increases in the planet's surface temperature between 1951 and 2010 were as a result of human causes, in particular the discharge of greenhouse gases (GHG) by human activity (IPCC, 2014a). Such a determination is also backed by Walsh *et al*. (2014) who comment that normal controllers of climate are unable to describe the current heating up of the planet in the last fifty years. As a fact, natural factors (volcanoes and solar forcing) only would lead to a slight cooling of the atmosphere. Hence, Walsh *et al*. (2014) and the IPCC (2018) concluded that the observed heating up of the planet in the last fifty years has been caused by man-made activities such as the discharge of GHG from the combustion of fossil energy sources as well as forest clearing.

Reddy (2014) states that GHG in the earth's atmosphere trap solar energy in the form of heat and influence the climate. These GHG emulate a blanket covering the earth where the denser the layer or the more concentrated the GHG become, the warmer earth becomes. According to Reddy (2014), the primary sources of GHG are the burning of fossil energy sources, mainly coal, oil, and natural gas. Thermal electrical energy generation has the highest effect on the atmospheric GHG concentration than all other individual anthropogenic activities. Global thermal electricity production emits about 23 billion tons of carbon dioxide (CO_2), whereby the burning of coal releases 70% more carbon than natural gas per kilowatt of electricity generated. The IPCC (2014a) reported that over three-quarters of total GHG produced in 2010 came from burning fossil energy sources. In a natural system, plants and, in particular, forests assimilate carbon from the air in the form of carbon dioxide, thus reducing its concentrations in the atmosphere. This process is known as carbon sequestration. Regrettably, deforestation practices currently taking place at a global scale limit carbon sequestration and, actually, release carbon back into the air (Reddy, 2014). Other land uses activities such as livestock farming also cause change for example Hong *et al.* (2021) states that beef production was the second highest contributor of all land-use GHG emissions in 2017, measured in terms of million tons carbon dioxide equivalent per year and this is mainly due to enteric fermentation and the release of methane.

3.3 Climate change impacts on the environment

Cubasch *et al.* (2013) state that indicators of a change in climate are many and comprise, for example, changes in: surface temperature, precipitation, atmospheric water vapour, severe climatic events, glaciers, and sea level. Walsh *et al*. (2014), for example, note that temperature indicators include the land surface, the oceans, and troposphere whose average temperatures' have risen since the 1980s with the highest temperature rise in the Polar Regions resulting in the melting of polar ice sheets. As a matter of fact the IPCC (2013) states that the heating up of the planets is evident where "globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 °C for the period 1880 to 2012". They further note that in the last 30 years surface temperatures' have been continuously hotter than any period since 1850. As a fact the last thirty years were the hottest era in the past 1400 years for places North of the equator. The heating of the earth has seen the melting of mainly the polar cryoshpere resulting average rise of 20cm in ocean level, between 1901 and 2010. The IPCC (2014a) further expands their observation by noting that on average the oceans temperatures rose by over 0.4 °C over a forty year period ending in 2010. The oceans of the world are the energy store on earth, and any change in their energy affects the climate of the earth.

With regard to the precipitation, Walsh *et al*. (2014) note that a hotter planet equates to a hotter atmosphere, and an increase in its water holding capacity. This has led to increased evaporation and precipitation in some areas on earth, as a matter of fact, the temperate areas in the areas north of the equator have on average received more precipitation from 1901. Walsh *et al*. (2014) further concur with this observation by also reporting that Atlantic cyclone and tropical storm activity, in the form of extent, occurrence and strength had increased substantially from 1980. Other observations, linked with a heating planet that take place in the oceans, are changes in their surface saltiness, which can also be linked to evidence of a change in the water cycle. High salinity (saltiness) in the ocean is common in areas where evaporation dominates, and low saltiness in areas with high rainfall (IPCC, 2014a).

The other climatic induced changes that are observed include acidification of the ocean due to increased marine uptake of carbon dioxide. As a given, oceans waters have become more acidic by 0.1 between 1992 and 2011. Globally, there has been changes from the normal, with an intensification or decrease in adverse climatic events; for example, heat-days and floods intensified while extreme cold days diminished (Walsh *et al*., 2014).

This observation was also mentioned by the IPCC (2014a) who noted that anthropogenic factors have affected most of the climate change indicators such that: the global water cycle has changed since the 1960s; glaciers have retreated since the 1960s; global mean sea level has risen since the 1970s; upper ocean (0–700 m) water temperatures have risen; and changes in the onset of the rain season have been noted in various places (Walsh *et al*., 2014). Pohl *et al.* (2017) project that by the end of the 21st century, Southern Africa will have a significant decrease total rainy days in conjunction with a significant increase in rainfall amounts for the wettest days.

3.4 Climate change impacts on agricultural systems

Agricultural systems remain highly dependent on weather and climate worldwide; hence such systems are impacted by change in climate either favourably or unfavourably (Battisti & Naylor, 2009). Accordingly, agriculturalists have highly adapted to deal with day to day or even year on year climate variability. At a local scale, a high level of adjustment is required to deal with the local climate variance, and such adjustment could include changes to infrastructure at the farm or a change in farming methods. The changes in climate can affect agriculture in two ways: by either endangering the establishment or by availing options for betterment of the farm (Gornall *et al.,* 2010). The deviations in climate beyond the normal state usually require modifications of the existing agricultural practices for the purpose of sustaining production (Gornall *et al*., 2010).

3.4.1 Impacts of climate change on cropping systems

The agricultural systems practised in any place are determined and dependent on the climate of that place; for example, changes in temperatures during the growing period of crops can significantly influence the agricultural yields which can impact on both the farmers' income and food availability (Battisti & Naylor, 2009). As already stated, the impact of climate change to agricultural systems will differ from area to area. In reality Gornall *et al*. (2010) state that for tropical regions it is expected that an increase in temperature is likely to be more directly damaging on crops due to higher evapotranspiration, and likely wilting due to increased heat and loss of water in these regions. Such effects are more likely because existing temperatures is near the biological limits of crops. While in some areas in the mid-latitudes a change in temperature by two degrees Celsius will likely raise wheat yields by about 10 %; however, around or within the tropical regions a similar temperature increase will possibly diminish harvests by a similar percentage. Porter *et al*. (2014) concurred with this finding by stating that changes in climate have adversely impacted grain production in several grain producing areas around the world, while warming due to climate change has positively impacted on yields in the sub-arctic regions; for example, the temperate area of northeast China and the United Kingdom. Olesen and Bindi (2002) observed that in the northern areas of Europe, a warming climate will possibly have beneficial impacts on crop farming because higher yields are expected from the existing ones due to the use of more suitable crop varieties and the enlargement in crop producing areas. Ramirez-Villegas *et al*., (2021) while studying climate change impacts in Southern Africa revealed that the region is open to climate change vulnerabilities such as: increased temperatures during the growing season, a reduced growing season and increased risk of drought. These risks are projected to reduce the climate suitability of crops such as beans, wheat, sorghum and maize and thus increasing the regions risk of food insecurity. While another study from the region on crop responses to climate change revealed that climate change will result negative impact on crops, for example a decline of about one-fifth in maize yields is anticipated, (Zinyengere *et al.,* 2013). An additional study from the region, by Zinyengere *et al.,* (2014), on the impacts of climate change on selected crops (maize and sorghum) indicated that the impacts on crops vary spatially and with the crop type and variety. Where some crops will be negatively impacted others will be positively impacted. Therefore implementing adaptation actions, such as drought monitoring, growing drought-resilient varieties and using drought insurance are crucial at supplementing long lasting food security strategies (Verschuur *et al*., 2021)

When considering the gains or losses to agriculture due to temperature increase, it is of importance to note that water is vital to plant growth; therefore, climate change will also see alteration in rainfall distribution and amount. This also might have a significant impact on agriculture. Climate change will likely have mixed variation on rainfall throughout the world, so it will affect agricultural systems differently. Given that 80% of the food production in the world is dependant on rain, projected changes in rainfall patterns are likely to assist in determining the impact of changes in rainfall on food production. Reilly *et al.* (2003) say that risks associated with climate change and agriculture will probably occur at a regional level due to changes in precipitation, or from complex climate-agriculture-environment interactions. Human caused climate change as well as impacting water availability (runoff) will affect water demand. This observation is supported by (Doll, 2002) who stated that if a region becomes warmer and drier, the decreased water availability will be aggravated by an increased water demand.

3.4.2 Climate Change Impacts on Livestock Systems

Porter *et al*. (2014) affirms that in contrast to cultivated agriculture and fish farming, there has been significantly less researched work on how climate variability affects livestock farming systems. This view is similar to that put forward by Thornton and Herrero (2015) who state that mixed crop–livestock systems are the backbone of African agriculture but are impacted by climate change. For these systems, the impacts of climate change have been greatly researched and are known for crop systems and less on the livestock systems. In spite of the aforementioned, there exists however some relevant literature about climate change impacts on livestock systems from around the world as well as in Africa. Outlined next are some examples from literature of how climate change impacts on livestock.

According to Assan (2014) climatic change is a threat to livestock farming systems around the globe because it strengthens negative stimuli like increased temperatures, reduced rainfall or shifts in rainfall distribution and droughts which result in reduced production. These can result in impacts such as reduction in herd size, reduction livestock fertility, reduction milk production, availability of fodder, (Montcho *et al.,* 2022).The negative impacts of climate change on livestock farming of can be either primary or secondary in nature (Thornton & Gerber, 2010). These primary negative impacts could be enhanced through hyperthermia or diminished water accessibility, while the secondary effects could result in a reduction in the accessibility to feed or fodder, the standard of feed or fodder, the development of diseases and increased competition for resources with alternative agricultural or economic systems (Thornton *et al*., 2015; Thornton & Gerber, 2010).

In livestock farming that practises zero grazing, the primary effects of climate change are likely to be minimal due to such farming taking place indoors which minimises exposure to climate variance (Thornton & Gerber, 2010). Furthermore, in zero-grazing systems the secondary impacts of significance will include reduction in yields, and lower food crop yields, animal food shortage, and increased energy costs. Thornton and Gerber (2010) further state that primary or secondary impacts of climate change will have varying impacts on either grazing or non-grazing livestock systems, Table 3.1 below outlines the types of climate impacts on livestock farming systems.

Table 3-1: Type of impacts of climate change on livestock farming systems

Impact Type	Grazing land / extensive systems	Zero-grazing / Intensive systems
Primary	• higher incidence of extreme climate phenomena • higher incidences and extent of droughts and floods • Reduced Production in view of increased temperatures • variance in water accessibility (could rise or fall depending on area)	• Variance in water accessibility (could rise or fall depending on area) • Higher incidence of extreme climate phenomena will have lower impact than on gazing land farming
Secondary	• Agro ecosystems changes resulting in: • Variation in gazing characteristics and amount • Transformation in host–pathogen contact leading to amplified occurrence of diseases • illness outbreaks	• Higher costs of food water and power. • Illness outbreaks • Higher expenditure on housing or air conditioning

(Adopted from Thornton and Gerber, 2010:174)

3.4.2.1 Climate change impacts on livestock with in the region

Climate change impacts in most African countries are further compounded by the fact that their peoples are notably susceptible to climate induced impacts, mainly due to severe scarcity of resources and a poor ability to adapt. For instance, inadequate information, financial constraints, skills scarcity, land scarcity, and limited possibilities for crop watering are presented to be causing farmers vulnerability to climate change (Deressa *et al.,* 2008). Factors such as famine, epidemics, internal strife, unrest and inadequate leadership aggravate susceptibility. Sivakumar *et al* (2005) note that about 30% of the planet's terrestrial area can be classified as dry land, and most is used for rearing livestock. These dry lands areas have lower rainfall than the evaporative demand (Tietjen & Jeltsch, 2007), and are also associated with high rainfall variability which directly influences the primary production of grasses. This is also a major influence on the carrying capacity of the grazing resources for livestock. One of the dominant land uses in these semi-arid to arid rangelands is the production of livestock, as a matter of fact, these regions support about 50% of the world's livestock (Tietjen & Jeltsch, 2007).

Thompson (2016), states that about 80% of the people of Eswatini live in the country side and depend on mixed farming for their sustenance. Furthermore, over 69% of these persons live below the economic threshold, rendering the susceptible to a variety of exogenous factors like epidemics, drought, floods, and climate change (Thompson, 2016).

Livestock farming is a dominant source of revenue for the majority of the population in Eswatini. It provides the farmers with a source sustenance by means of revenue, foodstuffs, manure, property or wealth, draught power for farm cultivation, as well as marriage obligations such as dowry (Ministry of Agriculture and Cooperatives 2004; Musemwa, Muchenje, Mushunje & Zhou, 2012). The majority of livestock rearing occurs in the Lowveld of Eswatini, whose savannah is characterised by semi-arid climate. Sivakumar, Das and Brunini (2005) note that about 30% of the planet's terrestrial area can be classified as dry land, and most is used for rearing livestock. These dry lands areas have lower rainfall than the evaporative demand (Tietjen & Jeltsch, 2007), and are also associated with high rainfall variability which directly influences the primary production of grasses. This is also a major influence on the carrying capacity of the grazing resources for livestock. One of the dominant land uses in these semi-arid to arid rangelands is the production of livestock, as a matter of fact, these regions support about 50% of the world's livestock (Tietjen & Jeltsch, 2007). Lastly, livestock grazing management also significantly influence vegetation dynamics in these areas whereby plant species composition change because of land utilization by the livestock (Assan, 2014; Thornton *et al*., 2015). An increase in grazing pressure and climate change leads to a reduction of palatable grass and legumes species which also results in reduced livestock productivity (Assan, 2014; Thornton *et al*., 2015). These findings are corroborated by a recent study by by Ramirez-Villegas *et al*. (2021) on climate change and its impacts in Southern Africa which revealed that climate change will have negative impacts on livestock farming systems by decreasing the suitability of land for livestock farming from reduced pasture productivity and increasing heat or temperature related stress on livestock.

Climate change will likely exacerbate all the above mentioned difficulties faced in the rearing or management of livestock in semi-arid or arid areas. Climate forecasts indicate that climate change will make many dry regions drier, while wet regions' mean precipitation will likely increase (IPCC, 2013). Similar inferences were made by authors such as Tietjen and Jeltsch (2007) and Assan (2014) who revealed that forecast for precipitation in arid and semi-arid areas of the globe indicate that annual precipitation will decrease and; furthermore, there will be a reduction in rain days throughout the rainfall season.

3.5 Climate trends and their use to determine climate change

Outlined below is how climate trends are used in climate change studies and the methods used to evaluate a change in or "climate change" as along with the methods proposed for evaluating climate change trends in the Lowveld of Swaziland.

3.5.1 Climate change trends

Human induced or anthropogenic climate is amongst the most prominent environmental challenges affecting planet earth (Weart, 2004). Climate change according to the IPCC (2014b:5) is "any change in climate over time, whether due to natural variability or as a result of human activity". This definition is different from that of the United Nations Framework Convention on Climate Change (UNFCCC) (1992:3) highlighting that "climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of global atmosphere and that is in addition to natural climate variability observed over comparable time periods". Climate change is not global warming, which refers to increasing worldwide temperatures mainly due to green-house gases increase, but it refers to change in regional climate conditions. Hence "climate change" would be described using parameters such as: temperature, rainfall, wind, humidity, air pressure and severe weather events (Kandji *et al.,* 2006; Brown *et al.,* 2012). For instance, presently climate change pertains to an increased temperature in many areas of the globe: an increase or decrease in precipitation; an increase in mean sea level; and an increase in occurrence and magnitude of climate extremes (IPCC, 2007b).

Climate change trends in Africa south of the Sahara, as observed by Archer *et al.,* (2010), indicate that region has become hotter over the past decades. Studies by Smith *et al*. (2001) quantify this rise in temperatures for the region to be over 0.5 ^{o}C for the last 100 years. Uwimbabazi *et al.* (2022) while studying meteorological drought events over Rwanda. Furthermore studies confirm that the region has become warmer in recent decades (Sylla *et al*., 2016; Jury, 2018; Ayugi *et al*., 2020; Uwimbabazi *et al*., 2022).While a study done Namibia quantify this increase in temperature as at 1.15 ^{o}C between 1950 and 2000 (Government of Namibia, 2002). The region has also witnessed a descending trend in precipitation that is also characterized by frequent drought events, for example in Zimbabwe rainfall decreased by 20% from the 1970s to the early 1990s and in this period, three extreme drought events were also observed (Chagutah, 2010). This observation is inline of that by Engelbrecht *et al.* (2015) who revealed that in the southern African region. In addition to the changes in temperature, rainfall will also be impacted, the conditions of dryness which usually peak by mid-October under present-day climate may change in the future to peak in December and essentially meaning a short growing season for mainly rain fed crops.Based on the above, it is evident that trends in climate parameters such as temperature, rainfall, wind, humidity, air pressure, and severe weather events are used to determine and evaluate climate change.

Some authors propose that climate change could be easily understood by studying changes in extreme climatic phenomenon as opposed to studying average climatic conditions (Groisman *et al.,* 2005; New *et al.,* 2006). In fact Groisman *et al*. (2005) suggest that with respect to normal climate trend analysis, trends in extreme climatic events are more likely to be straightforward in understanding climate changes. Studies using extreme climate events to indicate climate change have been carried in various parts of Africa; for example, research on extremes temperature trends in western, central and southern Africa, display a growing trend in favour of warm extremes while a declining trend in favour of cold extremes (New *et al*., 2006; Unganai, 2009; Aguilar *et al*., 2009; Addisu *et al.,* 2015).While such studies on extreme climate events are conducted, climate change is also impacted by GHG emissions so any change in emissions can also impact on extreme events, such an argument is highlighted by Nangombe *et al.* (2018), who note that recent climate forcing's are likely to intensify the magnitude and frequency of extreme climatic events in Africa however, little research has been done on the impact of the Paris Agreement targets on these extreme climate events in Africa.

3.5.2 The Use of trends to determine climate change

Climatic data is used to determine climate change by indicating if there is no change or showing a decreasing or increasing trend. Understanding such trends is vital for understanding interventions to assist with adaptations measures as well as policy interventions. The need to establish climate trends for developing countries, especially in Africa, is relevant since this region is understood to be most exposed to climate change effects (IPCC, 2007a; Niang *et al*., 2014; Serdeczny *et al*., 2017).

A number of studies were conducted using climate trends to assess the magnitude or trend of change in climatic variable. For instance, a study in Chitwan - India by Paudel *et al*. (2014) to establish and understand long-term climate trends in climatic data, for the years 1968 to 2007, made use of mean annual minimum and maximum temperatures as well as monthly and yearly rainfall data.

Studies in Africa indicated trends display hotter periods as compared with a century ago (Kurukulasuriya *et al*., 2006; van de Steeg *et al.,* 2009; Jury, 2019; Snaibi *et al.,* 2021; Habte, *et al.,* 2022). Similarly Sub-Saharan Africa has been undergoing a heating trend for the last few decades (Chishakwe, 2010; Archer *et al*., 2010; Jury, 2019). Such outcomes are comparable with a study from Zambia by Mulenga, Wineman and Sitko (2017) which examined climatic trends in three agro-ecological zones of Zambia as well as farmers' perceptions. The results showed strong indication that Zambia had become hotter over the past 30 years while the rainfall trend results indicated varying trends with such as an increase per agro-ecological zone.

3.5.3 The Use of Drought Indexes to Quantify Droughts

Climate extremes such as droughts tend to cause catastrophic impacts on many sectors for example on agriculture and the environment. In the past the prediction of droughts with regards to their onset, intensity, magnitude, duration, spatial extent and end of drought was difficult to determine (Vicente-Serrano *et al*., 2010). However, techniques and indexes to quantify droughts and monitor wet and dry periods have been developed (Ionita *et al*., 2016) and widely used drought indexes include the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI).

The Standardized Precipitation Index (SPI) is the most frequently used drought index, in fact, Hayes *et al.* (2011) states that the World Meteorological Organization in 2009 recommended the SPI as the main drought index to be used by countries to monitor droughts (WMO, 2012). Its strength is that it can be used anywhere and at various timescales (Hayes *et al.*, 2011). The SPI assist in providing scientific information on droughts and can classify various types of drought namely hydrological, agricultural or environmental drought (Mlenga *et al*., 2019). Its limitation is that, it only uses precipitation and does not reflect on other variables that can influence droughts, such as temperature, evapotranspiration, wind speed and soil water holding capacity (Taylor *et al*., 2012).

The Standardized Precipitation Evapotranspiration Index (SPEI) was developed to consider precipitation and temperature data (Vicente-Serrano *et al.,* 2010). Mathematically, the SPEI is similar to the standardized precipitation index (SPI), but it includes the role of temperature. However its advantage over the SPI is that it considers the effect of potential evapotranspiration on drought severity and it has multi-scalar characteristics that enable identification of different drought types and effects in the context of global warming (Vicente-Serrano *et al.,* 2010).

Drought indexes especially the SPI and SPEI have been used for evaluating the impact of climate change on short and medium term drought in an area (Lee *et al*., 2017). A case in point is the use of the SPI to evaluate the impact of climate change on the drought of a given area, by establishing the frequency changes in the drought events that might accompany climate change. As well as the testing of severity, duration, intensity and trend projections using probable prospective climate change scenarios (Lee *et al*., 2017).

Samples of its use in Eswatini come from two recent studies, one study by Mlenga *et al.* (2019) used the SPI for determining the spatiotemporal variability of droughts and revealed that there was an increase in drought frequency, severity and geospatial coverage over the past decades. Secondly moderate droughts are common while the occurrence of severe droughts is low. Hence the country is susceptible to mild and moderate droughts (Mlenga *et al.,* 2019). While a similar study done in Eswatini by Tfwala *et al.* (2020) investigating the spatial and temporal variability of droughts using data from 1981–2018 and the SPI revealed that the prevalence of droughts and their severity after the year 2000 has increased especially in the Lowveld. The drought frequency was higher in the drier areas of the country as opposed to the wetter areas and lastly that the drought trends are mostly increasing across the country (Tfwala *et al.* 2020).

3.5.4 Methods of trend analysis to determine climate change

A number of studies to establish climate change trends in climatic variables like temperature and precipitation have been carried out by various scholars (Yu *et al.,* 1993; Basistha *et al.,* 2009; Longobardi &Villani, 2009; Morin, 2011; Panda, 2016; Paudel *et al.,* 2014; Mulenga, *et al*., 2017). In these studies the climate variables were analysed for trends using either parametric and/or non-parametric statistical procedures. Parametric tests, namely the t-test, regression coefficients, and non-parametric tests like the Mann–Kendall (M-K) test and Sen's slope test for trend analysis were utilised.

Onoz and Bayazit (2003) state that the parametric *t* -test is weaker or less useful when compared with the non-parametric M-K test in data that has an unequal distribution; however, in actual implementation, both tests can be used mutually and for most times they yield the same outcomes. Scholars such as Longobardi and Villani (2009), while studying rainfall data from the Mediterranean, observe that the parametric *t*-test measures if the slope coefficient of the fitted linear regression is significantly divergent from zero, which would indicate the existence of a linear trend, and the slope coefficient mark would show if the trend is increasing or decreasing. The M-K test, on the other hand, confirms the presence with regards to an increasing or decreasing trend per given significance level. Such trends can be evaluated equally on a seasonal or yearly time scale.

A study in Chitwan - India by Paudel *et al*. (2014) to establish long-term climate trends using climatic data for the years 1968 to 2007, that consisted mean annual, minimum and maximum temperatures as well as monthly and yearly rainfall data, were analysed. For this exercise a nonparametric M-K statistical test was used. The reason they gave for using this test was because it was straightforward, vigorous, and appropriate for non-normally spread data. For this test a confidence level of 5 % was applied to identify trends in the climatic data.

A study in Zambia by Mulenga, *et al*. (2017) to determine climate trends made use of simple regression, whereby the year was the independent regressor and rainfall variables were the dependent variables. In the output, simply the coefficient for the year and its resultant confidence level were stated per regression. The nonparametric M-K test was also used to corroborate the regression outcomes. These results, for example, proved that a month-to-month assessment of these trends showed that temperatures were rising throughout the monitoring period. Also, Morin (2011) conducted another study on trend detection for precipitation time series data using both the simple linear regression and the nonparametric M-K method.

From the above studies it was evident that the dominant test to identify tendency or trends in climate data was the M-K Test which has happened to be utilised by numerous scholars to analyse climatic time series data.

3.5.4.1 Mann–Kendall (M-K) method

The M-K Test equates to a simple non-parametric test for trend that is not reliant on, the extent of data, missing data, or unevenly spread out monitoring periods. It measures if a time-ordered body of data displays an upward or downward tendency, for a given level of significance. The M-K Test limitations is that it is affected by seasonal effects and, thus, needs a lot of data to determine trend in order to overcome the impact of seasonal effects.

Mann (1945) offered a non-parametric test for randomness against time that represents a certain utilisation of Kendall's test for correlation generally acknowledged as the 'Mann–Kendall' or the 'Kendall *t* test' (Kendall, 1962). Letting $X_1, X_2, \ldots, X_n$ be a sequence of measurements over time, Mann proposed to test the null hypothesis, H_0, that the data come from a population where the random variables are independent and identically distributed. The alternative hypothesis, H1, is that the data follow a monotonic tendency over time. Under H_0, the M-K Test statistic is

$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(Xj\ -\ Xi)$ *1*

Where,

$$\operatorname{sgn}\ (\theta) = \begin{pmatrix} +1 & \dots.0 & > 0 \\ 0 & \dots.0 & = 0 \\ -0 & \dots0 & < 0 \end{pmatrix} \qquad 2$$

Under the hypothesis of independent and randomly distributed random variables, when $n \geq 8$, the *S* statistic is approximately normally distributed, with zero mean and variance as follows:

$$\sigma 2\ = \frac{n(n-1)(2n+5)}{18} \qquad (3)$$

As a result, the standardized *Z* statistics follow a normal distribution:

$$Z = \begin{pmatrix} \frac{S-1}{\sigma} & if & S > 0 \\ 0 & if & S = 0 \\ \frac{s+1}{\sigma} & if & s < 0 \end{pmatrix} \qquad (4)$$

The null hypothesis is rejected when the *Z* value calculated by Equation (4) is bigger in absolute value than the critical value $Z\alpha$, at a chosen level of significance α.

3.5.4.2 *Sen's Slope Estimator*

The Sen's slope estimator (SSE) has been applied extensively for evaluating climatological time series data (Salmi *et al.,* 2002; Yue & Hashino 2003; Rahman & Dawood, 2017). The magnitude of trend is predicted by the SSE. The slope (T_i) for all the concern data pairs is calculated as Sen's (Sen, 1968)

$$f\ (t)\ =\ Qt\ +\ B \qquad (5)$$

Where Q in Equation (5), indicates slope, while B is a constant. In order to obtain the slope estimation (Q) the slopes (value) of the entire time series data were calculated:

$$Qi = (Xi - Xj)/j\ \text{-k} \qquad (6)$$

In the given Equation (6), i = 1, 2, 3, …, N, whereas, at time j and k (j > k), X_j and X_k are the values of data pairs, respectively. When Q_i is positive, it means an increasing or upward tendency, while the negative Q_i reveals decreasing or downward trend in time series analysis. Similarly, zero value indicates no trend. The unit of resultant Q_i would be the slope magnitude in original units per year or percent per year (Salmi *et al*., 2002; Rahman & Dawood, 2017).

3.6 Climate change vulnerability

The term *"vulnerability"* originates from geography, risk, hazards, and disaster studies. Vulnerability as a concept has significantly grown with the recent growth of environmental studies as well as the world's focus on disaster management studies (Wisner *et al.,* 2004; Archer *et al*., 2010). In spite of this growth, the word "*vulnerability*" does not have a universally accepted meaning due to multiple conceptualisations amongst various disciplines, (Kasperson *et al.,* 2003). For example, scholars such as Liverman (1990) state that vulnerability is compared to theories such as exposure, risk, marginality, resilience and adaptability. Contrastingly, in developmental studies vulnerability is conceptualised as an amalgamation of interventions and actions regarding social welfare.

On another note, vulnerability as defined by FANRPAN (2011) denotes an incapability to endure negative consequences of pressure connected to change in the environment as well as the inability to adapt to that pressure. Lastly, the (IPCC, 2014c:128) defines vulnerability as "the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed as a result of climate change effects". The diversity, in the conceptualization or meanings of the term *"vulnerability"* is due its use in multiple settings, where it denotes diverse hazards or diverse schemes vulnerable to such hazards or threats (Adger *et al*., 2007).

Conceptualizing climate change vulnerability from studies offers a number of different methodologies or views, namely:

i. Starting point and end point view on vulnerability
ii. Vulnerability is dependent on adaptive capacity
iii. Two dimensional classification (the 'external' and 'internal' sources of vulnerability)
iv. The three dimensions of vulnerability to climate change
v. Seven criteria by the IPCC (2007) and Archer *et al*. (2010)

3.6.1 Vulnerability as a starting point and end point

Firstly, as a "starting point," view on vulnerability, means the state of vulnerability occurs inside the system prior to the incident or hazard. Or secondly as the "end point," view on vulnerability, means the amount of damage produced on a system via specific climate-related hazards or event (Kelly & Adger, 2000; Brooks *et al.,* 2005).

As a **"starting point"**, vulnerability has its origins in studies on food insecurity (Bohle *et al.,* 1994). Using this approach, vulnerability of anything to a natural hazard (climate change) is determined by its capability to react to such hazard in their present state, rather than the future state. In this approach vulnerability determines adaptive capacity (Kelly & Adger, 2000). Using a **"starting point"** vulnerability in climate change vulnerability studies is mainly used for the improvement or determination of adaptive capacity (Füssel & Klein 2004; O'Brien *et al.,* 004).

From an **"end point"**, vulnerability is projected to be seen as the net impact of climate change. Or the end point that begins with future emission, projections and trends, future atmospheric scenarios, then identifying climate impacts and adaptation options linked to adaptive capacity, (O'Brien *et al*., 2004). Thereby, adaptive capacity means the capacity to implement certain technical adaptations to climate change (O'Brien *et al*., 2004)

3.6.2 Vulnerability is determined by adaptive capacity

Vulnerability is dependant on either domestic or society's adaptive capacity. This relates to how the home or society is able to modify or change in response to change in climate such that likely harm or impacts are minimised, and beneficial impacts are exploited (Chagutah, 2010).

3.6.3 The Two dimensional classification

Climate change vulnerability can be described or summarised using a two aspects characterisation with an external aspect, that is characterized by the 'exposure' to climatic variability and an internal aspect, which involves 'sensitivity' climatic pressure (Ellis, 2000; Füssel and Klein, 2006; Archer *et al*., 2010).

3.6.4 Three dimensions of vulnerability

According to Moss *et al.* (2001), vulnerability to change in climate can be classified using a three dimensional approach that considers the changes in the physical environment as a result of the climatic shock; for example, yield losses due to drought. The second dimension considers the socio-economic environment of the homestead or community, and how such enables recovery from climate related shocks. The last dimension considers outside support to enable recovery from climate related shocks; for example, food aid provided by the Government.

3.6.5 Seven principles to determine climate change vulnerability

The IPCC (2007) and Archer *et al*. (2010) propose seven principles to determine climate change vulnerabilities. The particular principles are: the extent, timing, endurance, reversibility of the impacts, as well as the adjustment or adaptation likelihood to the shock, and lastly how important is the system exposed to the shock.

3.6.6 Farmers vulnerability (livelihood) to climate change

The IPCC (2007a) terms vulnerability to climate change as "the degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes". People around the world are susceptible to the climate change impacts particularly if the climate change affects their right to use resources and assets. For instance, persons with dependable and adequate access to financial, cultural, political, or physical resources such as food, water and sanitation, education and financial resources, will certainly have limited vulnerability to climate change shocks and stresses (Dodman *et al*., 2009, Ribot, 2010). Blakie *et al*. (1994) state that, from a livelihood perspective, the capacity of a household or community to use resources depends on it age, gender, ethnicity and socio-economic status, to name a few; whereby the less the access to resources required to provide a livelihood, increased vulnerability is observed. Ribot (2010) notes that the interaction between factors such as socio-economic, cultural, and political strengthen or weaken vulnerability. This observation provided conclusions used by scholars that predicted climate change impacts are aggravated by poverty.

On another note Smit *et al.* (2001), state that the vulnerability of poor people is greatly influenced by their biophysical environment, where most often, the poor inhabit areas that have significantly higher exposure to climate risks. Thus the livelihoods of poor populations of such environments are regularly also under great risk from climate change impacts. Such areas are called climate change ''hot spots''. These areas are basically characterised by areas with strong climate change signal combined with dense populations of vulnerable, poor, or marginalized people. De Souza *et al.* (2015) state that three known hot spots are the following:

(i) Semiarid areas of Africa along with South and Central Asia,
(ii) Deltas in Africa and South Asia,

(iii)The Himalayas river basins

Africa's population livelihoods are highly susceptibility to climate change because Africa is extremely dependent on agricultural production which is climate sensitive for her GDP. As a fact, agriculture contributes between 30 to 40 per cent of the Sub-Saharan countries' GDP (Kaijage, 2012). Furthermore, this vulnerability is also enhanced by both little adaptive capability as a result of high poverty levels for most African states, as well as the continuing unsustainable resource management practices that lead to degradation of the natural resources (agricultural land, rangelands, wetlands, and forests) which in turn reduces the capacity of these natural resources to adjust to changes brought by climate change (Kaijage, 2012). Other factors resulting in high vulnerability in Africa include: widespread poverty, high illiteracy rate, poor healthcare, low GDP per capita, weak institutions, poor infrastructure and technology, poor gender based policy planning, limited access to capital and markets, and increased disease burden (HIV/AIDS and Malaria) (Kasimbazi, 2009).

According to Thornton and Herrero (2008), a number of zones in Africa south of the Sahara are vulnerable to climate change. These include the drier zones in Southern Africa, the semi-arid ranges of East Africa, and last but not least the Sahel. These zones will probably experience significant effects of climate change, and furthermore, they are vulnerable to desertification (Boko *et al*., 2007; IPCC (2014). Hence the residents from these zones are clearly susceptible to the impacts of climate, considering that agriculture is the backbone to their livelihoods (De Souza *et al*., 2015).

As stated by Descheemaeker *et al.* (2016), over and above other risks farmers have to handle, climate variability has made smallholder farming more vulnerable farming to risks; furthermore, the absence of insurance and financial assistance as well, and price increase shocks compounds the situation (Laube *et al.,* 2012). Climate change is expected to result in amplified extreme climate which will reduce farm investment and input use contributing to inevitably reduced farm yield and earnings (Porter *et al*., 2014). When these climate change shocks strike, their impacts on income, resources, and food availability could be experienced instantly or in the long term; thus raising the probability of smallholder farmers dropping into poverty (Dercon, 2004). Incidentally, according to Shewmake (2008), the findings of a vulnerability study from South Africa concluded that families that are more vulnerable are those with no livestock, many members or big populations, and relied on dry land farming. Furthermore, those frequently impacted by climate shocks were the underprivileged, female headed households and big households. In the same way, Matarira *et al*. (2013) state that, in pastoral Southern Africa, peoples' vulnerability is related to their exposure to climate stress and their sensitivity to climate impacts; whereby sensitivity relates to livelihood resources such as financial, human, natural, physical and social (DFID, 1999). Therefore, poverty can be said to be at least the utmost noticeable gauge of climate change vulnerability among people and communities (Ribot, 2010).

3.6.7 Methods used to reduce vulnerability in livestock component

In accordance with findings by Panthi *et al*. (2016), while assessing climate change impacts on mixed agro-livestock smallholders in Nepal, some strategies to reduce vulnerability could include increasing food security; increasing water availability; improving awareness on impacts; and lastly improving income and livelihood diversification. While a similar study by Valbuena *et al.* (2015), on livestock farmers in mixed agricultural systems of crops and animals, they use crop residues as feed to reduce the livestock's vulnerability to climate change. The crop residue or leftovers are usually fed to animals when grazing is minimal in the dry season. In mixed systems, climate change also affects crop farming, and this has a ripple effect on animal farming (Descheemaeker *et al*., 2016). In spite of these impacts on crop and livestock farming in farms with mixed farming systems, the impacts related to climate tend to be less than in non-mixed systems because of the interdependence crop and livestock farming have on each other. Crane *et al.* (2017) state that in order to reduce vulnerability, policy initiatives and technical innovations that aim to achieve widespread reduction of vulnerability are needed. On another note, a study in east Australia on livestock systems by Marshall *et al.* (2018) concluded that in order to reduce vulnerability in the livestock sector there needs to be focused attention on all the impacts of climate change; for example, the biophysical, ecological and socio-economic as well as investment to increase. Also linked to this is the need for investment to enlarge the farmers' capacity to adapt to climate impacts.

3.6.8 Methodologies for climate change vulnerability assessment

Climate change vulnerability is dynamic and depends upon both biophysical and social processes (IPCC 2014). Methodologies for vulnerability assessment try to answer queries about its causes and effects. Also, feedbacks could be employed to minimise its causes and effects. Correspondingly, according to Opiyo *et al.* (2014), methodologies that can be used to study vulnerability to climate change can be categorised as either biophysical (*impact assessment),* socio-economic, or methodologies that incorporates biophysical methods and socio-economic methods.

3.6.8.1 The biophysical methods

The biophysical methods try to determine the magnitude of impact from environmental pressure. This method is commonly called an impact assessment. According to Hewitt (1995) this method is the main method used in studying vulnerability to climate variability or change (Liverman, 1990). Füssel (2007) classified this method as a risk-hazard method. Though the biophysical methods is a useful tool, it has major shortcomings. The foremost shortcoming relates to its emphasis on physical damages; for instance, the impacts on harvest for assessment of biophysical factors is inadequate for appreciating the intricacies of vulnerability. Furthermore, the method does not consider the human activities and governmental influences on the vulnerability and or how to adapt to it (Pulwarty & Riebsame, 1997).

3.6.8.2 The socio-economic method

The socio-economic assessment methodology considers the socio-economic and political standing of persons or communities (Opiyo *et al*., 2014). Since persons in society have varying socio-economic standards such as literacy, affluence, well-being status and gender, they have varied levels of vulnerability to a particular climatic stress (Füssel 2007 & Deressa *et al*., 2008). Due to these varying socio-economic factors, vulnerability is, therefore, well-thought-out as a state or a basic state in a system before the stress or exposure occurrence (Kelly and Adger, 2000).

The main drawback linked to this method is that it concentrates on socio-economic and political differences inside society, and ignores the fact that such variations are not only as a result of socio-political issues but also environmental issues. Furthermore, this method fails to consider natural resource that can minimise negative impacts of environmental shocks such as climate change. For example, proximity to a water source assist in dealing with dry spells as opposed to areas far from a water source (Deressa *et al*., 2008).

3.6.8.3 The integrated method

This method considers an association of biophysical and socio-economic methods. This method embraces all conditions and states of vulnerability. Vulnerability to climate is characterized as some function of exposure, sensitivity, and adaptive capacity (IPCC 2001; Füssel, 2007; and Füssel and Klein, 2006). This method can be explained in equation 1 (IPCC, 2001).

Vulnerability = f (Exposure x Sensitivity x Adaptive Capacity) (1)

Furthermore, O'Brien *et al. (*2004) suggest the vulnerability mapping method is another example in which both the integrated method is utilised to point out the level of vulnerability through mapping. In another study by Binita *et al.* (2015) the integrated method was used to compute vulnerability by incorporating human and environment systems. In this study they integrated spatial vulnerability, social vulnerability, and bio-physical vulnerability as per the IPCC (2007c) and Cutter *et al.,* (2003) frameworks. This method provided an innovative procedure to describe continuing climate vulnerability by combining step by step changes in climate plus extreme climate events, on the one hand, and antecedent social vulnerability, at the same time for the climate vulnerability assessment.

This method attempts to address the shortcomings of the other methods; however, it also possesses its own. The main shortcoming is that there is no uniform procedure for bringing together the biophysical and socio-economic methods. For example, it uses varying data sets like for socio-economic literacy and income, while for biophysical it could use temperature and rainfall. Another shortcoming for this method is that it does not consider the changes in vulnerability. In spite of these limitations, this method has much to offer in that it minimises the risks associated with the other methods.

3.6.9 Approaches for determining climate change vulnerability

As discussed above, many methods exist for studying vulnerability to climate change. The common standard approaches employed in vulnerability literature include the indicator approaches and the econometric approaches which are deliberated below.

3.6.9.1 Indicator approach

The indicator approach makes use of a unique set or grouping of indicators then systematically combining them by calculating indices and the arithmetic mean for the preferred indicators, to point out or measure the extent of vulnerability. This approach can be used in multiple settings such as at household level, community level, national level, regional scale, and at global scales (Deressa, 2007).

These indicators can be developed or adopted from various indicators or from complex indicators in other disciplines, such as sustainable development, or adopted for use from the Index of human insecurity (Lonergan *et al.,* 2000; Luers *et al.,* 2003; Gbetibouo & Ringler, 2009).

In the calculation of the level of vulnerability using the indicator approach two methods are available and these are:

i. The indicators are set identical weighting: this assumes the indicators are equally important (Cutter *et al.,* 2000).
ii. The Indicators are set diverse weightings: this assumes the indicators are diverse, with unequal importance hence the diversity in weighting.

Most studies use this method of unequal weighting. The approaches used to provide these weightings suggest the use of expert judgment, the use of principal component analysis, and relationship with historical disaster events (Deressa 2007; Nkondze *et al*., 2014). Deressa (2007) notes that even though weighting is done, there is lack of precision due to the absence of standardised methods; thus, there is some subjectivity. This statement is supported by Luers *et al*. (2003) who states that the approach is limited by subjectivity of choosing the indicators and their comparative weighting, and the trouble verifying or authenticating them. In spite of these constraints, the indicator approach is the principal method accepted for measuring vulnerability to global change, and also it provides superior insight to the socio-economic and biophysical factors favourable for vulnerability (Gbetibouo & Ringler, 2011).

3.6.9.2 The econometric approach

The econometric approach is related to poverty and development studies, and it makes use of data obtained from the household level to examine vulnerability levels of diverse community groupings. The assessments methods makes use of three types of vulnerability, namely: as an expected poverty, as expected utility, and as an exposure to risk (Hoddinott & Quisumbing, 2003).

All methods quantity loss are linked to impacts; however, the vulnerability as an expected poverty and vulnerability as an expected utility quantity indicates the likelihood of a household's consumption dropping lower than a minimum level in the future as a result of present or former impacts; while vulnerability as an exposure to risk quantifies after the event wellbeing loss. The most frequently mentioned impacts include: climatic, economic, and political impacts (Hoddinott & Quisumbing, 2003).

3.7 Farmers' perception of climate change

Niang *et al*. (2014) state that in order for humans to undertake any action towards climate change adaptation, they have to perceive the changes in the climate, and such views should be reinforced by reliable climatic data (Ziervogel *et al.,* 2008). This notion is supported by Nguyen *et al.,* (2016) who indicate that a farmer's perception of changes in climate strongly correlate with his or her learning experiences and adaptation options. As noted by Simelton *et al*. (2013), acknowledging how climate is perceived by farmers at the farm level is important to predict the effects of the change in climate. This is because it is the farmers who anticipate or identify a problem associated with changes in climate, then they have to develop strategies to counter or adapt to those changes. In fact Kuivanen *et al.,* (2015) state that climate change perceptions are a key indispensable necessity for adaptation. Therefore a comprehensive understanding of factors persuading farmers views of climate change are essential in the development of farm level adaptation plans (Megersa, *et al.,* 2014; Aswani *et al.,* 2015). Thus, an incentive to consider farmers' perceptions of climate change is crucial because knowledge of change and farmers' perceptions of the associated climate impact is a precondition for the development and implementation of adaptation plans (Mulenga *et al.,* 2017). Farmers' views have significant effect to the farmers handling of climate-induced threats and opportunities. It is their attitudes towards their views on climate change that determine the adaptation preferences (Adger *et al.,* 2009; Debela *et al.,* 2015). In Addition, Mulenga *et al*. (2017) indicated that there was inadequate information on how various socio-environmental issues affect small scale cattle farmers' views on the impacts of climate change, and thus, this study will also solicit how these factors influence farmers' perceptions in Eswatini.

3.7.1 Farmers' perceptions from around the world

Farmers' perceptions of climate change have been widely studied and vary with region. As an illustration, Brondizio and Moran (2008) while conducting a study in the Amazon, discovered that farmers could not perceive correctly past climate events such as droughts and El Nino related climatic events and thus exposure to these climate extremes did not lead to adaptation. While a study by Pandey (2019), in the Middle-Mountains of Nepal, studying residents views on climate change in the area revealed that: over 50% of respondents reported extended periods of water scarcity that had adversely impacted on farming. Furthermore, 75% of the respondents perceived that the flow in water sources (rivers and springs) had diminished. They also thought that the causes of the droughts and the decreased water flow in rivers were linked to decreased precipitation especially during winter. There was a justifiable correlation between the farmers' observations (perceptions) and climatic variables.

Likewise in Africa, various studies on livestock farmers' perceptions or views about change in climate have been conducted, and outlined below are some of the key findings of these studies. Data from a survey (> 8 000 respondents) by Nhemachena and Hassan (2007) of agricultural households across 11 countries in Africa, determining farmers' perceptions of climate change as well as approaches for adaptation to such perceptions revealed a number of things. When respondents were questioned about temperature and rainfall perceptions, they answered as follows: 50% of the farmers perceived that long-term temperatures were increasing (warming), whereas the other 50% believed precipitation was declining. About 33% perceived there were noticeable changes in the onset of the rains, and, last but not least, one sixth of the farmers perceived the frequency of droughts had increased. A similar study was conducted by Maddison (2007) on perceptions of change in climate for farmers in 11 countries across Africa. The results revealed that most respondents believed temperatures had risen and rainfall was reduced. Furthermore, statistical analysis revealed that the farmers' experience on farming determined the perception.

In northern Africa, while studying the perception and adaptation to climate variability and change of Moroccan pastoralists, Snaibi *et al*. (2021) observed that the pastoralists had perceived that since the 1970s there had been a significant decrease in yearly rainfall, an increase in temperatures, drought frequency and high winds. Such perceptions were perfectly supported by observed climate data trends. Also concluded was that the negative impacts of climate change on small ruminants were the reduction in water accessibility, rangeland fodder production and enhanced degradation of gazing lands as well as increased poverty and inequality (Snaibi *et al*., 2021).

While a study conducted in Ghana by Fosu-Mensah *et al.* (2012) investigating farmers' perceptions of climatic data and vegetative cover for the past 20 years. The results indicated that the majority (over 90%) of the farmers noted that temperatures had changed, and above 85% of them noted that rainfall was getting less. The climatic data for temperature correlated. The farmers (80%) reported that the increased temperatures were due to deforestation with the rest linking temperature increase to other factors, while the majority of the farmers associated reduced rainfall with deforestation. Whereas a study by Idrissou *et al.* (2020), from Benin, on cattle farmers revealed that the main perception of climate change was reduced rainfall and an increase in temperature and strong winds. Moreover a study from West Africa by Montcho *et al.* (2022) on dairy farmers perceptions and adaptation strategies to climate change revealed that the dairy farmers perceived a decrease in length of the rainy season and increase in the dry season; a decrease in annual rainfall with an increase in average annual temperatures and these change in climate affected their farming activities resulting in a reduction in herd size, livestock fertility, milk production, availability of fodder.

Whereas in a survey investigating smallholder farmers' perceptions and adaptations in Eastern Kenya, indicated that the farmers regarded extreme climatic conditions, such as drought and floods, as a serious variables which affected crop and livestock farming. With regard to flooding, the farmers mentioned that flooding led to poor yields. The main hazard mentioned to be associated with drought was water shortage; while for floods it was water logging, and livestock loses were associated with both hazards. Lastly, the farmers noted that temperature increases led to higher incidences of pests on their crops and more diseases to livestock (Kichamu *et al.,* 2018). An additional study from East Africa by Habte *et al*., (2022), studying the effects of climate variability on livestock productivity and the farmer's perception in South-eastern Ethiopia, discovered the observed drought trends and climate trends corresponded with the farmers' perception with regard to trend and direction.

A study by Kuivanen *et al.* (2015) on farmers' perceptions and responses to climate change in Southern Africa revealed that perceptions on climate change by farmers are able to provide valued insights on the extent and impact of climate change and such perceptions can oppose the views believed by researchers' and policy-makers. At times, perceptions of climate change seem to be consistent with actual climatological data but generally these views contrast climatological evidence. This findings are corroborated by those of a study in Zambia, on climate trends and farmers' perceptions indicated that the country's temperatures had risen for the last 30 years, while precipitation varied with an increase in the Eastern Province and a shortened rain season in the Northern Province. When comparing the empirical evidence with farmers' perceptions, the results show that, with regards to temperatures, there was a correlation of empirical data and the farmers' views while the rainfall records and perceptions did not correlate (Mulenga *et al*., 2017).

Examples of studies from Southern Africa on perceptions include a study on smallholder cattle farmers in Malawi that indicated that the farmers' views were that changes in climate negatively affected the amount and quality of beef produced by their livestock in the last 20 years (Chingala *et al.,* 2017). Other perceptions about changes in climate were: firstly, an increase in pest (ticks and internal parasites) reported by over 60% of the farmers. Secondly, a reduction in food which led to reduced yields of both meat and milk. This view was reported by a majority (over 70%) of the farmers. Thirdly, a reduced breeding or herd growth rate, and an increase in death rate for the head. These views were reported by a minority (at least 40 percent) of the farmers. A logit model was used to explain what factors influence these farmers' perceptions. The results indicated that the location, sex, reasons for rearing cattle, and earnings significantly ($p < 0.05$) influenced these perceptions. For example, farmers who only derived earnings from the farm had a greater ($p < 0.05$ perception of delayed calving than those who had other sources of income, while female led families had a greater perception ($p < 0.05$) about increased livestock deaths as opposed to male led families. Whereas farmers with higher levels of illiteracy showed a greater ($p < 0.05$) perception of reduced revenue. In spite all the views about the detrimental impacts of change in climate on their livestock, the farmers did not have defined adaptation plans (Chingala, *et al.*, 2017).

Another study on perceptions from the region is a study on farmers' perceptions of climate change impacts and adaptation measures from South Africa's Eastern Cape which revealed that smallholder farmers noticed that temperatures had risen while precipitation declined. This led to increased drought and resulted in reduced farming activity due to drought related challenges such as; water scarceness, increased epidemics, reduced yields and reduced farm earnings (Popoola *et al.,* 2018).

While a local study on farmers' perception was conducted in northern Eswatini by Mamba *et al.* (2015), who reported that farmers' in northern Eswatini could differentiate between climate change and weather variability. There were, however, varying perceptions about the onset of the rain season, with the majority having perceptions correlating with rainfall records, while a minority had non-correlating perception to the onset of the rainy season. It was also observed that the farmers' perceptions affected the amount of money they spent on inputs as well as yields. Those who perceived the onset of the rain season correctly spent more on inputs and such led to food security. While those who had non-correlating perceptions on rainfall season spent less money on the farm, and thus, obtained reduced yields leading to food insecurity. Furthermore, the respondent's literacy rate and age correlated with perception on climate. With aged and literate farmers perceiving rain season onset more correctly (Mamba *et al*., 2015). The major conclusion from this study was that farmers' perceptions affected inputs and this had a bearing on harvest and food security. Education and age were found to influence how farmers perceived rainfall conditions.

3.7.2 Approaches used to evaluate farmers perceptions of climate change

Various approaches have been used to analyse data on perceptions and to draw conclusions. Outlined below are some of these approaches from various studies.

A study by Maddison (2007) on climate change perceptions and adaptation consisted a comprehensive study of farmers from eleven countries in Africa. The study made use of various statistical methods to evaluate perception. These methods are the Heckman's sample selectivity probit model, spatial autocorrelation, and the comparison between farmers' perception with historical meteorological data. The results of each method are discussed below:

- *The Heckman's sample selectivity probit model* revealed that even if knowledgeable farmers were highly expected to perceive climate change, it was the literate farmers who were highly expected to react by adapting. Lastly, it was farmers who were close to markets to sell their produce and enjoyed free advisory services that were also highly expected to adapt (Maddison, 2007).

- *Autocorrelation analysis* was used to determine if climate change perceptions were spatially auto-correlated or, in simple terms, if individual interviewees' evaluations could be corroborated by adjacent farmers' answers. Spatial autocorrelation would not be anticipated in a data where interviewees were randomly reporting how they perceived climate change because; for example, they wanted to favorably provide the data the interviewer was looking for (Maddison, 2007). Maddison (2007) utilised the Moran's I test for spatial autocorrelation with an inverse distance weights matrix on the farmers who perceived certain types of climate change for a particular governmental area (as outlined by Anselin, 2001) of Niger and Ghana. The results from Niger appeared to be from regions where neighbouring farmers agreed that rainfall had risen, while the other were from where they agreed it had decreased. There were also regions where neighbouring farmers agreed that temperatures had remained constant. The Ghana results were more remarkable in regions where neighbouring farmers were individually asked about their perceptions of climate change, and they agreed that temperatures had risen or remained constant, while rainfall had risen or remained the same or that the rain season had changed. This was possibly the best illustration that farmers were able to perceive changes in climate and, furthermore, that neighbouring farmers shared similar perceptions (Maddison, 2007).

- *Comparison of farmers perceptions of climate change to meteorological data.* This was done by comparing the likelihood that the climate has changed, as indicated by analysis of the statistical record, with the proportion of individuals who believe that such a change has in fact occurred. Tests were undertaken for linear trends in annual means in maximum and minimum temperature, and annual rainfall totals (Maddison, 2007).

Similarly a survey conducted in the Ashanti region in Ghana by Fosu-Mensah *et al*. (2012) made use of questionnaires to study farmers' perception of climate changes and changes in, plant cover over the past 20 years. Other enquiries were made on adaptation and its impediment. To analyse the data, the logit model was utilised, and for the analysis the regressands were perception and adaptation. The predictor variables included: educational status, age, sex of household head, farming experience, farm area, and access to: market, extension services and loans.

The logit model was deemed the most appropriate because of the dichotomic nature of results of how the farmers perceived climate change and if they adapted. This model studies the association between a binary regressand and a set of predictor variables.

The logistic model for 'k' predictor variables $(x_1, x_2, x_3 \ldots, x_k)$ is given by

$$Logit\ P(x) = \propto + \sum_{i=1}^{k} \beta i X_i$$

Exp (βi) indicates the odds ratio for a person having characteristics i versus not having i, while βi is the regression coefficient, and α is a constant.

Moreover the study by Mandleni and Anim (2011) on the perceptions of livestock farmers, the analyses of data utilised both descriptive statistics and inferential statistical analysis (in the form of Principal Component Analysis (PCA)) of the variables selected. The descriptive information showed that ranchers had diverse views on climate change and its adaptation. The PCA was applied to categorise groups of interdependent variables in order to analyse concealed interrelationships between them. The variables, most descriptive, of the study were the effects of climate change livestock farming, climate change perceptions and aspects that swayed adaptation decisions. Additional enquiry with PCA disclosed that diverse perceptions of climate change could be broadly grouped as: temperature; drought and windy weather; information and adaptation; climate change and extension services; and finally, cattle and sheep farming.

On the other hand a study in Eswatini on crop farmers' perceptions of climate change, Mamba *et al*. (2015) used a questionnaire to collect data, and after coding and analysis, it used the following: frequencies, cross tabulations, and statistics to determine associations between variables. Results were displayed using graphical methods; for example, using bar graphs, pie charts, and frequency tables. For statistics in the form of correlation, ANOVA and chi-square were performed on the data to test for significance of the effect on crop yield, whilst correlation analysis was used for analysing the climatic data. Whereas Multiple Regression Analysis (ANOVA) was used to determine if climate change had an effect on crop farming.

3.8 Adaptation to climate change

The concept of adaptation to climate change is widely utilised and it relates to acclimatisation of living things to altered climatic conditions. In fact adaptation was a term used in the biology of evolution and Darwin's idea of survival of the fittest (Smit, 1993). This concept of acclimatisation has moved from being linked with animals and their reaction to a changing environment, and grown to an idea for minimising risk to persons due to climate change (Smit & Skinner, 2002). Climate change adaptation basically involves describing the adjustments, proactive and reactive, in our environment in reaction to current or anticipated changes in climate to minimize loss and enhance favourable prospects (IPCC 2007; Deressa *et al*., 2008; Descheemaeker *et al*., 2016). According to the IPCC (2007: 881) climate change adaptation is an "adjustment in ecological, social, or economic systems in response to actual or expected climatic stresses and their effects or impacts." It must be noted that this IPCC definition also embraces both climate change and variability. This research adopts the IPCC meaning of adaptation for use. Various studies outline various classifications and forms of adaptation to climate change; for example, adaptation could be classified as autonomous (spontaneous) or planned (reactive) adaptation (IPCC 2007a; FAO, 2013), or anticipatory adaptation or planned adaptation. These different kinds and interpretations of adaptation to climate change are outlined below:

(i) Reactive adaptation relates to any actions or decisions being applied retrospectively.
(ii) Anticipatory adaptation are actions and choices implemented prior to the impact or influence (Phuong, 2011).
(iii) Planned adaptation means an involvement of human work and efforts that were antecedently intended (Smith *et al*., 1996; IPCC, 2007a).

(iv) Autonomous adaptation refers to expected or impulsive changes against climate change (Smith *et al*., 1996; IPCC, 2007a).

Since climate change adaptation is a continual process it is difficult to differentiate anticipatory and reactive actions or decisions for adapting. Anticipatory adaptation needs farsightedness and preparation whereas reactive adaptation does not. On the ground, persons usually use a mixture of reactive and anticipatory approaches to deal with the impacts of change in climate. The FAO (2013) states that adaptation can either be an impulsive or planned process where persons or the public adapt to changes in climate.

According to the IPCC (2007a) and Mano and Nhemachena (2007), climate change adaptation in agriculture has been taking place as farmers have always lived with changing climate or climate variability: furthermore, they have revealed excellent resilience to climate variability or change. Cooper *et al.* 2008) and IPCC (2007a) indicate that adapting to existing climate change or variability could enhance the farmers adaptability to lasting climate change. In spite of the adaptation already being implemented, the farmers might not have the same resilience in the future because climate change is likely to happen quicker than present day change.

In agriculture adaptation takes place mainly at two stages, namely: the macro and micro level.

3.8.1 Climate change adaptation at macro level

Adaptation at the national level focuses on agricultural production at national/ regional scale and how this is influenced by national or regional policy (Bradshaw *et al.,* 2004; Kurukulasuriya & Rosenthal, 2003). A Macro-level analysis of climate change adaptation centres on crucial nationwide strategies which consider extended period of time changes in climate. For example, Zimbabwe and many other countries in the region are developing national frameworks aimed at countering climate change. These are anticipated to steer adaptation agendas (Brown *et al.,* 2013).

3.8.2 Climate change adaptation at micro level

At the micro level, adaptation centres on strategic choices agriculturalists make in reaction to variations in climatic, economic, and other factors (Di Falco *et al.,* 2012). Maddison (2007) and Deressa *et al.,* (2011) state that adaptation is done in two stages. Firstly, that of perceiving change in climate, and secondly, the response or adaptation. According to Hassan and Nhemachena (2008) adaptation at the micro level helps farmers reach their objectives in light of the changing climate. At this level, farmers' adaptations include alterations to farming practices. Normal adaptation responses to climate change for livestock farming include technological (for example, introduction of breeds), behavioural (for example, reduced consumption), managerial (for example, new approaches to farming), and policy aspects (for example, new regulations) (Silvestri *et al*., 2012). Livestock systems are better suited for climate change adaptation than cropping systems due to their mobility; for instance, livestock can be moved to areas where water and food is available during times of drought or food shortage (Silvestri *et al*., 2012; Thornton, 2010). Similarly, a study by Kuivanen *et al.* (2015) on farmers' perceptions and responses to climate change and variability in Southern Africa revealed that farmers' responses to climate change can be categorised as coping or adaptation strategies. Coping strategies are usually reactive and rather short term and can include responses to deal with a flood or drought e.g. the sale of assets. While adaptation strategies are generally longer term and can either be reactive or pre-emptive and can include for example diversifying crops or livestock and the use of supplementing feeding for livestock. Kuivanen *et al.* (2015) states that coping and adaptation actions can be grouped into six general categories namely:

a. crisis response;
b. modifying farming practices;
c. modifying crop and animal types, varieties and breeds;
d. natural resource management;
e. livelihood diversification and
f. knowledge management.

Whilst in Eswatini, a number of livelihood strategies are used by rural communities to cope with climate change. Such strategies include: the use of indigenous knowledge to predict or prevent hydrological and climate events and disasters, and the use of natural resources for food and income. Also, the traditional social support system, made up of neighbours, relatives, and members of the household is used to respond to natural disasters. This support system can either assist in providing food, favours, a source of income, and even with ploughing fields of affected families that have lost cattle due to climate change or natural disasters. Such favours can either be for free or in exchange for goods or favours (Manyatsi *et al.,* 2013). There are concepts which are directly associated with adaptation which need to be understood to fully comprehend climate change adaptation. These concepts are: Adaptive capacity and maladaptation

3.8.3 Adaptive capacity

Adaptive capacity is the "ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2001:72). Adaptive capacity has been characterised as the capability of a community to adapt to climate change; it is the essential or present capacity of a community to deal with climate impacts (Huq & Reid, 2009). Adaptive capacity is a function of the resources or means available that assist in starting adaptation. The key components creating adaptive capacity are centred on its main indicators; for example, technology, economic well-being, infrastructure, personnel resources, life expectancy, access to insurance, access to healthcare, and other universal development outcomes (Klein, 2001). Emerging nations are usually thought of as possessing the least adaptive capacity because they have poor access to technology, poorly developed societal institutions, and existing stresses associated with climate change (Chagutah, 2010). Adaptive capacity is inversely correlated with vulnerability. Therefore, the bigger the adaptive capacity, the least vulnerable societies are to change in climate, and the more successful shall be adaptation to change in climate. From this, it is evident that the concept of adaptive capacity is hinged to resilience, where the more resilient a component is, then the better its ability is to adapt; and the less vulnerable it is to risks. Consequently, if adapting reduces vulnerability, so improved adaptive capacity will strengthen adaptation and build resilience to change in climate.

3.8.4 Maladaptation to climate change

Maladaptation is where adaptation initiatives increase instead of reducing vulnerability to change in climate. Maladaptation is "an adaptation that does not succeed in reducing vulnerability, but increases it instead", IPCC (2001: 990); for example, the moving of marginal fields in a drought year. Another example is the use of water for irrigation during a severe drought that could result in more serious adverse consequences for downstream users. Such a scenario can not only strengthen vulnerability, but may as well create new risks (Smit *et al*., 2000).

3.8.5 Worldwide studies on climate change adaptation measures by farmers

Various research on farmers' adaptation to climate change have been carried out around the world. Outlined below are some examples of such studies from Sub-Saharan Africa.

A study from west Africa on climate change adaptation strategies implemented by the farmers in Oyo State, Nigeria are: farmers always take early rains into consideration before planting (71.7%); use indigenous knowledge in weather forecast (70.8%) prior to planting decisions; engage in alternative income generating activities (60.0%); practise zero tillage (52.5%); plant new varieties (46.7%); use organic fertilisers (41.7%); practise mixed farming (38.3%); and practise multiple cropping (35.8%) (Borokini *et al.* 2014).

While a study from East Africa, on climate change perceptions and adaptations of small scale farmers in Eastern Kenya, observed that on-going farm-level adaptation approaches utilised by the farmers could be categorised into both short-term and long-term agricultural production tactics, even though most the farmers use short-term approaches. In drought years, the farmers cull animals at the beginning of the drought. They use drought resistant crop varieties, and participate in non-farming activities to complement their earnings. They manage diseases or pests in their livestock and crops, and also engage in rearing small livestock in effort to reduce their climate risks vulnerability (Kichamu *et al*., 2018). The factors identified by the participants as limiting adoption of climate adaptation strategies were: inadequate knowledge of adaptation measures caused by limited number of extension workers to capacitate the farmers; the exorbitant price associated with the implementation of adaptation plans, for instance, building water collecting structures. They also noted regular erroneous weather forecasts which forced farmers to withdraw from early planting of crops. The factors identified by the participants as enhancing adoption of the climate adaptation strategies were: improved harvests, positive market prices, and government assistance (Kichamu *et al*., 2018).

Whereas a study from South Africa on farmers' perceptions of climate change and adaptation from the Limpopo Province of South Africa by Maponya and Mpandeli (2013), revealed that farmers' perceived adaptation strategies included: soil management strategies, water management strategies, the use of subsidies, and the use of insurance. The farmers identified the following adaptation barriers: insufficient information, lack of government support, and inadequate education and skills. The authors concluded that addressing these barriers would significantly help farmers to tailor their management practices to withstand climate change, and would also increase their adaptive capacity.

At a local level, in a semi-rural area of Eswatini, adaptation action proposed by farmers to adapt to climate change included the following: the provision of water for irrigation (57%); construction of dams and other structures to harvest and store rainwater (23 %); revival of agricultural extension services (13 %); and lastly, access to loans for small and medium enterprises (6%) (Vilane *et al*., 2015).

3.8.6 Climate change adaptation measures in livestock farming

Various studies on climate adaptation measures from around the globe include a more recent study in the United Kingdom by Wreford and Topp (2020) on climate change impacts of on livestock and possible adaptations revealed that even though many adaptations are available to farmers their adoption and implementation is comparatively low because there are many barriers to the implementation of adaptations. Also indicated in the study was that farmers are less likely to consider adaptation to long term change impacts and there is therefore a need to increase their awareness of such impacts.

A study from North Africa by Snaibi *et al.* (2021) while studying pastoralists' perception and adaptation to climate variability and change in Morocco observed the farmers' adaptation was affected by the wealth categories of the farmers, where wealthier farmers adopted a greater range of approaches, while poorer pastoralists used less diverse adaptation strategies.

On the other hand studies from West Africa by Comoé and Siegrist (2015) on livestock farmers' behaviour regarding adaptation to climate change, in Côte d'Ivoire observed that two main strategies were employed for adaptation to climate change. Firstly, reducing animal herd sizes for more adequate grazing during droughts and for improved condition of the livestock was observed, and secondly, it was increasing livestock's movements to enable access to grazing. While a study by Idrissou *et al*., (2020) investigating cattle farmers climate change adaptation strategies of in two regions of Benin revealed that the farmers minimise the harmful influences of climate change by applying seven diverse adaptation approaches, that included transhumance (moving livestock from one grazing to another in a seasonal cycle), crop and livestock farming, the use supplementary feed concentrates, livestock diversification, culling, forage cropping and off-farm activities.

Studies on adaptation from East Africa include a study by Tesfaye and Nayak (2022) identifying different climate change adaptation strategies used by farmers households in Ethiopia that revealed five adaptation options used by the farmers and these were agro-forestry, soil and water conservation, small-scale irrigation, crop diversification and adjusting planting dates. Whereas another study from Southeastern Ethiopia, by Habte *et al.* (2022), on the effects of climate variability on livestock productivity indicated that to adapt the farmers also practiced transhumance, reduced animal numbers, harvested and stored hay and shifted to browsers such as camel and goat instead of grazers.

While in Kenya, a study by Ifejika-Speranza (2010) on understanding adaptations to climate change in the livestock producing regions of Kenya, observed that insights for climate change adaptation were determined by using drought impacts and farmers coping approaches, as descriptive examples. The farmers' reaction to drought were relatively reactive and mostly intensified utilisation of current resources, while embracing less proactive approaches. Furthermore, the agro-pastoralists implemented strategies that included increasing livestock sales and relocation to remote pastures as an adaptation measure, though in some cases the farm level adaptive capacities were regularly inadequate, thus, requiring food aid interventions. In another study by Ifejika Speranza *et al.* (2010) on indigenous knowledge related to climate change in semi-arid areas of Kenya, it was observed that agro-pastoralists were unable to alter their farming methods in reaction to indigenous knowledge forecast of drought despite the richness of the indigenous knowledge indicators and the high confidence that the farmers have in them. The study further found that factors such as poverty and inadequate resources by the agro-pastoralists to implement the desired adaptation strategies, also limited the role of indigenous knowledge to contribute to pathways to reduce the adverse effects of global climate change. Therefore, for a significant climate change adaptation by the agro-pastoralists, it was essential that the linkages between poverty and vulnerability be addressed. This study concluded that without addressing these constraints between poverty and vulnerability, forecasts, whether from indigenous knowledge or formal sources, may not generate any significant adaptations to climate by these farmers.

While another study in Kenya by Silvestri *et al*. (2012) on climate change perception and adaptation amongst livestock farming communities, it was observed that the foremost adaptation strategies comprised: relocating livestock to an alternative location; providing supplementary feed; changing animal breeds; and engaging in mixed agriculture. Constraints also limited adaptation options. Other desired but constrained options comprised: irrigation, agroforestry, altering crop types, altering animal breeds, and expanding the herd size. In general, the reported constraints that limited adaptation included: financial constraints (by a majority of the farmers); inadequate credit to farmers; limited access to land; poor market access; and lack of water. In the study, it was observed that a number of variables swayed climate change adaptation, and these included: literacy rate of household head; farm and non-farm earnings; food aid received; use of livestock extension services; access to training on livestock farming; and use of weather forecasts. In this study; for example, the literacy rate of the household head meaningfully increased the chance that ranchers reduce their livestock numbers. The results proposed that more affluent households were highly likely to adapt to climate change (Silvestri *et al*., 2012).

Examples of studies of from southern Africa include a study from Botswana by Kgosikoma and Batisani (2014) on livestock population dynamics and pastoral communities' adaptation to rainfall variability in Kgalagadi South, Botswana discovered that pastoral farmers' adaptation strategies include destocking, feed supplementation and mobility. A similar conclusion was made by Akinyemi (2017) in the semiarid Palapye area of Eastern Botswana. While another study from Botswana by Kgosikoma *et al*. (2018) revealed that the adaptation strategies used by livestock farmers in Botswana were supplementary feeding, vaccination and provision of shading or livestock housing.

At a local level a study by Khumalo (2018) on agro-ecological location of farms and choice of drought coping strategies used by smallholder farmers in Eswatini revealed that for coping or adaption to droughts the farmers purchased water and hay for livestock, constructed livestock shelter, changed livestock types to more drought tolerant types such as goats and migrated livestock to areas with better grazing.

In conclusion, studies of acclimatising (adapting) farming to climate change in Africa have resulted in significant research on farmers perceptions and adaptations (for example, Howden *et al*., 2007; Deressa *et al*., 2009; Ifejika-Speranza, 2010; Ifejika-Speranza *et al*., 2010; Silvestri *et al*., 2012; Below *et al*., 2012; Fosu-Mensah *et al*., 2012; Comoé & Siegrist, 2015, Wreford & Topp 2020; Idrissou *et al*., 2020; Snaibi *et al*., 2021; Tesfaye & Nayak, 2022; Habte *et al*., 2022). The general deduction drawn from these studies noted that the majority of farmers perceive that there is change in climate and, as such, have introduced a number of adaptation actions to lessen the impact. For example, a study by Below *et al*. (2012), when reviewing adaptation in African agriculture, recognized about 104 different adaptation practices used to adapt to climate change. These practices were largely grouped into: farm management, managing the farm finances, farm diversification and off-farm income generation, government interventions, and knowledge management.

3.8.7 Climate change adaptation strategies for livestock farming

Climate change has impacts on livestock farming because it affects the natural resources livestock are dependant on as well as biodiversity and livestock health (Thornton, 2010). Such impacts have direct effects on livestock farming and the farmers' livelihoods as well as the country's GDP. Thus, to minimize the impacts of changing climate on livestock farming, adaptation must be implemented (Thornton, 2010).

According to Porter *et al*. (2014), livestock farming systems occupy a great variety of biophysical and socio-ecological scenes that ensure an assortment of possible adaptations. In general, livestock farming systems are highly adjusted to past and current climate risks which provide an opening for climate change adaptation (Rust & Rust, 2013). According to Nardone *et al.,* (2010), climate change adaptations could include matching stocking rates with grazing; managing diet quality; providing supplements; and lastly monitoring and managing pests, disease and weeds.

On another note, Iglesias *et al*. (2012) state that climate change adaptation strategies are comprehensive action plans usually implemented through methods or measures and policies. These adaptation strategies are not just responses to climate change threats, but can include as well a large number of social, technical, environmental and economic challenges (Iglesias, *et al*., 2007; Iglesias *et al*., 2012). The development of adaptation actions must consider both future socio-economic scenarios, as well as, future climate change scenarios. According to Silvestri *et al*. (2012), collective adaptive responses utilised by livestock farmers to respond to climate change include: technological (for example, introduction of breeds); behavioural (for instance, reduced consumption); managerial (for example, new approaches to farming); and policy approaches (for instance, new regulations). Wilk *et al.,* (2013) state that, in some countries climate change adaptation strategies are rooted in climate forecasts, to augment opportunities and decrease risks.

3.8.8 Methodology for Identifying and evaluating adaptation in agriculture

According to Iglesias *et al*. (2012), the methodology for classifying and appraising adaptation measures has three key elements, namely: the identification of adaptation measures, the evaluation of national adaptation frameworks, and the consultation of stakeholders.

3.8.8.1 *Identification of adaptation measures.*

Here, possible adaptation actions are proposed for all the climate change risks and opportunities. Such measures are mainly obtained from academic publications, reports on adaptation, and expert judgement (Iglesias *et al*., 2012). For the risks identified, the possible adaptation responses, either at policy, sector or farm level, are evaluated based on: technical difficulty, costs, and benefits of implementation (Iglesias *et al*., 2012).

These adaptation measures are then additionally classified as technical (for example, introduction of new breeds), infrastructural (for instance, changes in drainage), or managerial (for example, changes in cropping patterns). The type of adaptation measure is largely determined by how much the farmers can use them without outside help (Iglesias *et al*., 2012).

The timescales for implementation of adaptation measures have to be determined and classified. They are classified as: short-term (< 5 years), medium-term (5-10 years), and long-term (> 10 years). These timescales relate to standard timescales for farm business planning (Iglesias *et al*., 2012). Many adaptation measures are implemented somewhat swiftly by different farmers in reaction to impacts. In these cases, the schedule of implementation is controlled by either costs of technical ability of the farmer. Therefore, the measures usually implemented are short-term and require low costs (Iglesias *et al*., 2012).

3.8.8.2 *Review of national adaptation framework.*

An appraisal of national adaptation strategies is also carried out on policies connected to agricultural climate change adaptation.

3.8.8.3 *Stakeholder consultation by questionnaire*

A questionnaire is used to gather data on current and intended adaptation actions relating to agriculture. This assist in filling crucial knowledge gaps relating to climate change adaptation measures (Iglesias *et al*., 2012).

3.8.9 *Methodologies used to analyse farmers adaptation to climate change*

After reviewing these studies the question is, how? According to Fussel (2007), there are various methods or guidelines developed by international organisations for assessing climate change adaptation. These guidelines are the IPCC Technical Guidelines (Parry & Carter, 1998), the

USCSP International Handbook (Benioff *et al.,* 1996), the UNEP Handbook (Feenstra *et al.,* 1998), the UNDP-GEF Adaptation Policy Framework (Burton *et al.,* 2005), and the Climate Change Adaptation through Integrated Risk Assessment (CCAIRR) Guidelines (Asian Development Bank, 2005). Burton *et al*. (2005) state that two ideal approaches used for the assessment of climate impact and adaptation assessment are the hazards-based approach and the vulnerability-based approach.

3.8.9.1 The hazards-based approach:

According to Fussel (2007), this method centres on the cumulative climate change impacts. The assessment begins with modelling climate change projections and minor attention of non-climate elements. The key disadvantages of the hazards-based approaches are their overdependence on model-supported climate projections that are usually on different scales with the researchers needs. In addition, these approaches usually do not offer much insight to non-modelled aspects such as an adaptive capacity and policy framework in that setting (Fussel, 2007).

3.8.9.2 The vulnerability-based approach:

Fussel (2007) states that the vulnerability-based approaches evaluate future changes in climate against the background of existing climate risks. This approach concentrates mainly on social aspects that shape one's ability to deal with climate change vulnerabilities. Vulnerability-based assessment involves linking stakeholders and their activities from the beginning with climate change adaptation. This method produces worthwhile outcomes even when there are no reliable impact projections. The disadvantages of this approach include more reliance on expert judgment, lack of a standard methodology, and limited comparability across regions.

3.8.10 Methods for evaluating climate change adaptation in agriculture

Maddison (2007) reviewed the adoption process and cites two main approaches used to study the factors of implementation of agricultural innovations, namely: the probit and logit models. Seo and Mendelsohn (2007) used multinomial logit models to study farmers' choices of crop and livestock as an adaptation choice. The outcomes from the choice models illustrated that farmers in hotter regions are likely to choose goats and sheep instead of cattle, as an option for adaptation; reason being that goats and sheep are better suited for drier conditions than cattle.

Furthermore, Maddison (2007) employed the Heckman selection probit approach to explain the factors influencing African farmers' adaptation strategies. The results obtained indicated farmer experience, usage of agricultural extension services, and usage of markets were key factors influencing adaptation.

While Hassan and Nhemachena (2008) acknowledged that climate change adaptation at both the macro and micro level have been studied and evaluated using diverse approaches, they noted that at the lowest level adaptation to climate change has been analysed using the multinomial logit approach. Reason for using this approach is that it has a wide application in adopting decisions that analyse the causes or reasons of farmers' decisions to adapt to climate change involving multiple adoption choices.

Silvestri *et al*. (2012), in a study in Kenya on 640 households owning livestock, the logistic regression approach was utilised to analyse the circumstances influencing farmers' adaptation decisions where the main adaptation choices (the regressand's) were the following: reducing stock, switching breeds, changing feeds, and trans-locating livestock to other areas. The predictor variables were chosen on the rationale of earlier studies (Pender, 2004; Baltenweck *et al.*, 2003). With regards to factors influencing adaptation, variables used included the following: sex of the household head; education and years of experience of the household head; household size; income and livestock ownership; extension and training received; access to climate forecasts; usage of formal or informal credit; distance to the closest commercial centre; and food or other aid received (Silvestri *et al*., 2012). Furthermore, in another study by Zizinga *et al*. (2017), the multinomial logit regression approach was utilised to analyse the determinants of farmer adaptation practices in south-western Uganda.

Lastly, in a study by Kumasi *et al.* (2019) on small scale farmers' adaptation options to climate change in north-eastern Ghana, both descriptive and quantitative statistics to analyse climate change adaptation practices were used. The Chi-square tests were used to compare variables at a 95% confidence interval. The variables tested included answers on climate change impacts, problems faced by the farmers, the adaptation plans used by male and female farmers, and farmers' knowledge of climate change and adaptation (Kumasi *et al*., 2019).

Maddison (2007) used autocorrelation analysis to determine whether adaptations or perceptions of climate change were geospatial auto correlated, that is, in simple terms, if specific farmers' valuations can be corroborated by neighbouring farmers' answers. Spatial autocorrelation is not expected when farmers are randomly indicating that they adapt or perceive change in climate, (Maddison, 2007).

Maddison (2007) employed Moran's I test for spatial autocorrelation with an inverse distance weights matrix on the portion of farmers who perceive particular types of climate change within a particular administrative area, as outlined by Anselin (2001) of Niger and Ghana. The results from Niger appeared to be from regions where neighbouring farmers agreed that rainfall had risen as well as from other regions where they agreed it had decreased. There were also regions where neighbouring farmers agreed that temperatures had remained constant. The Ghana results were more remarkable. In regions where neighbouring farmers were individually asked about their perceptions of climate change and they agreed that temperatures had risen or remained constant, while rainfall had risen or remained the same, or that the rain season had changed. This was possibly the best illustration that farmers were able to perceive changes in climate, and furthermore, that neighbouring farmers shared similar perceptions (Maddison, 2007).

3.9 Climate change adaptation policies and evaluation

In recent years, since 2001, the notion of adaptation as a theme necessitating a matched policy reaction has gained popularity and attention at both the local and international level (Bauer *et al.,* 2012; Biesbroek et al., 2010; Ford *et al.,* 2011).

At the international level, there are global conventions on climate change that have sections devoted to adaptation. At the national level, countries have domesticated these international adaptation policy plans into their development frameworks; furthermore, every country reports on how it has implemented a profile of these policies (Massey & Huitema, 2013). Webster (2002) states that climate change adaptation policy formulation poses a great challenge to decision-makers mainly because such presents a problem of uncertainty. Therefore, as climate change adaptation receives growing world-wide attention, the role of information in decision making for policy makers continuously becomes increasingly important and relevant mainly because there is an increased need for the formulation and delivery of effective adaptation policies. Furthermore, policy makers face the task of allocating scarce resources towards the formulation of these policies and plans. This inevitably raises questions as to the importance of accurate and precise information on future climate impacts which also compounds the complexity of decision-making structures on multiple levels of governance in different countries. Another challenge for policy makers is that the majority of climate adaptation policy development occurs on national scales, and the local communities are dependent on the national government for financial resources, climate information, and relevant policies to aid in climate adaptation (Westerhoff & Juhola, 2010).

According to Kaijage (2012), adaptation is the chief issue for African countries with respect to climate change. Adaptation in this context equates to modifications in social, economic, and ecological structures with regards to tangible climatic stimuli and its effects (Leary *et al.,* 2008). The fundamental factor for climate change adaptation should involve enhancing resilience or enhancing abilities of individuals, groups, and nations to face the impacts of climate change. Building a resilient society can be done by implementing various initiatives and policy options from the household level to the country level and up to the global level (Conway, 2009). Lastly, the implementation of policies that enable climate change adaptation in particular sectors such as for water management, farming, and healthcare, is important (Kaijage, 2012).

Ayers and Huq (2009) state that the UNFCCC Parties agreed to support climate change adaptation in low-income countries by mainstreaming it in official development assistance and establishing special adaptation funds. Holler (2014) notes that in response to these funds low-income countries, with the support and consultation from the UNFCCC, prepared National Adaptation Programs of Action (NAPAs) to harmonise global adaptation finance in order to minimise public vulnerability to climate change. The NAPA development guidelines assist in ensuring consistency with existing development plans as well as including sectoral policies for adaptation and poverty reduction, (Holler, 2014). An example to this is put forward by Yiran and Stringer (2017) from Ghana, where the majority of climate change policies are developed at the national level, in line with international commitments such as its obligations under the UNFCCC. These policies target sectors identified as extremely susceptible to climatic change risks, for example, farming and water management.

3.9.1 Types of climate change adaptation policies

Before discussing the types of policies it is of importance to understand, what a policy is. A "Policy" is a law, guideline, process, governmental measures, stimulus or intentional practice of governments and organizations. Generally policies function at the systems level and can effect complex systems in manners that could lead to socio-economic well-being of the country and its people.

There are different kinds of policies, and each one can function at diverse level such as international, national, local, or organizational level. Such policies include:

(i) Legislative policies which are rules produced by chosen legislatures.

(ii) Regulatory policies are formed by regulatory government agencies and include guidelines, procedures, values, or procedures for products or services.

(iii) Organizational policies created within an organization and comprise guidelines

One example of an international agreement is the 'Paris Agreement' that was established under the UNFCCC at the 21st Conference of the Parties in 2015 (UNFCCC, 2015). The Paris Pact builds on the Kyoto Protocol and lays down an agenda for nations to intervene on climate change. Under the Agreement, all countries have committed to lessen and acclimatise to climate change. Furthermore, the Treaty allows for the provision of support to help developing countries implement the agreement through training, technical, and financial support.

3.9.2 Climate change adaptation policy evaluation

According to Vedung (2005:13), policy evaluation is a "careful, retrospective assessment of merit, worth, and value of the administration, output and outcome of government interventions, which is intended to play a role in future practical action situations". Her Majesty's Treasury (2011) on the other hand, states that Policy evaluation uses a range of research methods to systematically investigate the effectiveness of policy interventions, implementation and processes, and to determine their merit, worth, or value in terms of improving the social and economic conditions of different stakeholders. Lastly, the definition put forward by Dunn (2004:35) suggests that evaluation is an "applied endeavour which uses multiple methods of inquiry and argument to produce and transform policy relevant information that may be utilized in political settings to resolve public problems".

3.9.3 Studies on climate change adaptation policy evaluation

According to Urwin and Jordan (2008), decision makers in most parts of society have grasped the necessity of integrating climate change into the development of public policy. The so called climate policy integration, spearheaded at a global and country level, has a strong bias on the mitigation of climate change and not on locally focused policy integration for climate change adaptation. For example, in the UK Urwin, and Jordan (2008) noted that the extent of the different sub-elements of policies either support or undermine potential adaptive responses in food production, environment protection and water management. For evaluation they used two types of approaches, namely: a top-down and a bottom-up approaches. The top-down approach utilised two methods, specifically policy documents content analysis as well as interviews with decision makers, while the bottom-up approach made use of interviews with players in organisations within the sectors studied. The study concluded that no one method offered a comprehensive view with regard to integration of different adaptation policies in the sectors studied, but combined, the two approaches offer a new approach for climate policy integration. Such results enlighten an argument on climate policy integration execution and evaluation such that they support rather than hinder adaptation.

Bonzanigo *et al.,* (2016), in their study on how farmers' experiences shaped or informed adaptation in Italy, observed that while there was a growing demand for agriculture to adapt to climate change, the only efforts usually encouraged are only those of the policy dimension, or planned adaptation option. Nevertheless, it is critical to include farmers' independent adaptation into the assessment of pastoral policy actions. This helps to ensure the effectiveness of the policies since the farmers are the primary receivers of climate-proofing agricultural policies. Thus, it is essential to include farmers in the design phase of these policies. The methodology used for this study made use of an online questionnaire to collect data on farmers' opinions of climate change and its adaptations. Once the data was collected the major determinants of their choices were determined using a multinomial probit model. The farmers' expectations of effectiveness of the different options of adaptation were analysed using an online decision support system tool, mDSSweb. The results were used by policy makers to understand how different types of farmers were adapting or not adapting to climate change. This study also assisted locating farmers who needed to be targeted first and with what type of support.

In a study to investigate the relationship between sectoral policies on woodlands, water resources and food production, the NAPA, the relevant development and conservation projects and the adaptive capacity in Mweka Village on Mount Kilimanjaro in Tanzania, it was found that the adaptation programs were formulated to ensure they were in agreement with sector specific policies and development programmes (Holler, 2014). However, such policies resulted in unbalanced and unfinished decentralization managing adaptation at the local level. Significant gaps exist between the policies and realities of adaptation in Tanzania; thus undermining the sustainability and social equity of adaptation. These gaps were a result of partial decentralization of the institutions and networks required for adaptation.

In a study to examine current climate change adaptation policy, its implementation, as well as the evaluation of obstacles to adaptation in Ghana, policy documents that covered key livelihood sectors (for example, food production, water resources, healthcare and climate change) were evaluated / reviewed (Yiran & Stringer, 2017). The Policy documents from the sectors mentioned above were collected from the institutions responsible for implementing such policies. The sector policies were reviewed and examined to determine the interplay between national policies and local practices, as well as to identify key areas of support and conflict, and the barriers to implementation of sectoral policies and local actions. For the documents reviewing, content analysis approach (qualitative document analysis) was followed. This method has been widely used by other scholars (WHO, 2009; Wesley, 2010).

The process followed involved: First, reading through the policy documents to identify and note focal areas that aided adaptation to climatic events. The noting involved identifying and recording of the objectives, actions, and outputs of the focal areas. The focal areas and their programmes / actions that address climatic hazards were identified and categorised. These include droughts/ high temperatures and flooding/heavy rainfall events. Next examined were the execution of policy actions and outcomes by analysing focus group discussions (FGDs), and in-depth interviews (IDIs) held with community members and officials using thematic content analysis. Here also, the notes were read and analysed to identify actions, following the same procedure adopted for the policy analysis. From the responses, also identified were actions that had been successfully implemented (local good practices), as well as highlighting barriers to implementation (Yiran & Stringer, 2017).

The findings indicated that most policy formulation used a top-down approach, with little or no participation from the community. Once formulated the policies would be executed at the local level. From the discussion with implementers and interviews with local people, it was recognised that several policy actions were implemented and well received by the actors while some had not. Local people have been adapting separately to the climatic hazards, and have, therefore, developed adaptive strategies that they consider successful. The evidence of this approach from the interviews was that incorporation of indigenous viewpoints into policies was required to improve adaptation. Furthermore, it was observed that despite the fact that policies and activities complemented one another, their consolidation was poor. There was also lack of local involvement in policy development that was noted to hamper adaptation (Yiran & Stringer, 2017).

In another study by England *et al* (2018), using examples from Malawi, Tanzania and Zambia, to investigate the degree of consistency in country policies for the water resources and farming sector to climate change adaptation objectives as per each country's' development plans, to investigate this, qualitative document analyses of appropriate policies as well as expert interviews in each country were used. The key findings indicated that sectoral policies had different levels of consistency on adaptation, where Zambia had the strongest consistency and Tanzania the weakest consistency. Also noted was that these sector specific policies were more consistent in tackling short-term problems such as floods and droughts as opposed to long-term climate adaptation plans. It was further noted that more recently developed policies and strategies had the strongest coherence as opposed to older ones.

3.9.4 Methodology for evaluation of climate change adaptation policies

Various methodologies have been used for evaluation of climate change adaptation policy. Outlined below are some studies and methodologies used to evaluate climate change adaptation policies. As an illustration, a study by Urwin and Jordan (2008) to evaluate if the country's policy assists or hinders climate change adaptation in the United Kingdom made use of two methodological approaches the top-down approach and the bottom-up approach. The top-down approach utilised two methods: content analysis for policy documents as well as interviews with decision makers at national level. The key policy documents utilised for content analysis were global treaties, Regional (EU) guidelines, and UK law.

The content analysis used the following criteria: firstly, the recording of every mention of climate adaptation. Secondly, the valuation of the capability of the policy to promote adaptation, and lastly, the findings were corroborated by key informant interviews held with the main actors or decision makers.

For the bottom-up approach Urwin, and Jordan (2008) used interviews with players in organisations with a mandate for policy implementation in the sectors studied. For these interviews, a set of integrated climate change and socioeconomic scenarios were developed and used as a guide. In the interviews, the interviewees were asked to assess the main policies that promoted or constrained climate adaptation (Urwin & Jordan, 2008).

Likewise, a study by Muchuru and Nhamo (2017) analysed and reviewed climate change adaptation actions from UNFCCC National Communications and the African livestock sector from 21 selected countries. The countries used in the study were purposefully sampled based on, initially, their very recent national communications reports (either the 2nd or 3rd) as posted on the UNFCCC website or repository, and secondly, that they were English speaking countries. The procedure also utilised a literature review method by conducting a thematic analysis and content analysis of the climate change impacts on livestock and a survey of the submitted adaptation actions. According to Braun and Clarke (2006:6), “Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data”. On the other hand, content analysis deliberately describes documents features by identifying patterns and providing frequency counts, and thus, offers quantitative analyses of qualitative data (Bloor & Wood, 2006; Braun & Clarke, 2006). In the same study, both approaches were used by the authors on the documents acquired from the national communication reports and this included: coding data features methodically; searching for themes and specific names; defining the themes; arranging and generating groups and explanations of the themes; and evaluating the results through a theoretical basis (Elo & Kyngäs, 2008). In addition, this methodology, the grounded theory methodology by Charmaz (1983), was used to interpret the retrieved information.

In the same way a study by Nhamo (2014), addressing women requirements in policies on climate change amongst nominated countries in eastern and southern Africa, eleven policies were evaluated by means of critical discourse and document analysis as outlined by Altheide (2000) to establish if and how women’s requirements were catered for in the policies. The non-probability sampling was used to choose the policies based on their online availability. According to Altheide (2000) tracking discourse and qualitative document analysis are appropriate methods used in analysis of openly accessible policy documents. This view is supported by Bowen (2009:27) who states that document analysis is “a systematic procedure for reviewing or evaluating documents both printed and electronic (computer-based and Internet-transmitted) material”. The first stage of analysis used by Nhamo (2014) involved counting the words “gender” and “women”. The second stage described all cases mentioning women in the climate change policies. The main findings of this study were that most of the national policies reviewed were in their infancy; the incorporation of women’s’ necessities in climate change policies had acquired stimulus, and the empowering of women by climate change policies varied across the countries studied.

Moreover, England *et al*. (2018) in Malawi, Tanzania and Zambia, investigated the degree of consistency in each country's state policies on water resources and agriculture to climate change adaptation using Qualitative Document Analysis (QDA) (Altheide *et al.,* 2008). In this study expert interviews were used for the analysis of policy documents. The QDA used in this study followed five steps of analysis, namely:

(i) Setting boundaries for document selection;
(ii) Finding the documents;
(iii) Documents analysis of;
(iv) Authentication;
(v) Completion (Altheide *et al*., 2008).

For Step 1, the document sample was taken from the three countries. For Step 2, internet searches for government and other relevant websites were used to locate the sector policies, and where online searches failed, documents were sourced from staff members from the relevant government.

Step 3 involved systematically analysing documents using a content analysis, to ascertain if adaptation was considered or not, and if climate change adaptation declarations were consistent with the other documents evaluated.

The content analysis approach used the following approach: firstly, the recognition of explicit key words like "irrigation", "drought", and "flood". Secondly, the usage of the key words to examine the parts in the document where they were located, in order to deliver country-specific context and insights into government plans and priorities. Thirdly, the search of key words within themes in other documents, and this was done to assess the extent of coherence (of the documents. For instance, how the agriculture policy, mentioned drought or water. A qualitative score was given to the level of coherence, ranging from 3 (full coherence) to 0 (no coherence). Fourthly, the assessment of the consistency of policies in relation to one another per country. This assessment used mean scores from the 3rd phase, such as, the coherence of Malawi's Agricultural Policy comparative to its Climate Change Policy is 2.5.

The fourth and fifth steps, namely: authentication and completion steps in the QDA respectively, consisted of expert interviews of key national government and nongovernmental personnel. These were also analysed based on thematic areas and policy significance.

3.10 Use of Climate Forecasts for Adaptation

According to Dorling (2014), the key components of forecasts designed for agricultural use may differ on both spatial and temporal scales, but the one thing they should have in common is climatic or weather information that can affect farming activities. These weather components can include all meteorological components; for example, sunshine hours, solar radiation, frost risk, dew risk and evapotranspiration, visibility, and extreme events such as floods and thunderstorms (World Meteorological Organization [WMO], 2010). Generally, most forecasts are obtained from government organisations that distribute the forecasts via print media, television or radio, and of late, electronic media including the internet. According to Wilk *et al.* (2017), seasonal climatological forecasts have become an essential part of disaster and risk planning, lately. In agriculture, for example, early warning systems based on forecast information could reduce smallholder farmers' drought risks and inform decisions and recommendations during the hazardous period (Wilk *et al*., 2017). Patt *et al.* (2005) state that the first major success in climate forecast application occurred in 1992 when the Brazilian state of Ceará warned farmers about a future El Niño, and to mitigate its impact, they supplied free drought-tolerant seeds, resulting in a dramatic increase in their yields over what they would have otherwise received (Golnaraghi & Kaul, 1995). Today, in a number of countries around the world (including South Africa and Eswatini) provide farmers with climatic forecasts tailored for agriculture, and in particular crop farming.

According to Klopper *et al.* (2006), another approach utilised for climate change adaptation is by using seasonal climate forecasts. This opinion is supported by Dorling (2014) who states that accurate and dependable climate forecasts are very essential in mitigating and adapting to extreme climates events in agriculture. O'Brien *et al.* (2000) note that seasonal climate forecasts have predicted changes in climate and events such as the arrival of El Niño and La Nina events since the mid 1980's. Thus, as these forecasts improved, their potential for social and economic applications became an issue of great interest. Seasonal forecasts can be used as a tool to support farmers and organizations to manage and adapt to climate variability (Klopper *et al*., 2006). Studies have indicated that it is both the availability of information from climate forecasts and the end-users capacity to act upon the information (O'Brien *et al*., 2000), or the adaptive capacity of the users of such forecasts (Klopper *et al*., 2006) that matters. For example, a study by O'Brien *et al*. (2000) examining small-scale farmers' responses to seasonal climate forecasts in Namibia and Tanzania noted that a minority of farmers indicated they had obtained pre-season climate forecasts, and the main reason was that such forecasts are not designed for the direct use of the small-scale farmers. Therefore, given the fact that the small farmer is not the direct target of the forecasts, its use and value is limited because the information it provides is only useful if the farmer can use the information to improve decision making and improve overall risk management, and increase economic benefits arising from the use of these forecasts.

It must also be noted that there are also non-climate factors that act on farmers' use of seasonal forecast information. Such non-climate or weather factors can include available capital, market factors, and agricultural policies. However, to have economic value, climate information has to be understood and used to support the farmers' decision-making process. For example, the commercial farmer usually uses forecasts in day-to-day planning and execution of farming operations. On seasonal time-scale, climate information influences decisions on to what to produce, when to plant, fertilizer applications, livestock management, and labour requirements (Klopper *et al.,* 2006). In a farming environment, reliable seasonal forecasts could be very valuable in forward planning, and in investment decisions on farm operations. Other important management decisions on the farm, for example, in commercial livestock production can include: expected pasture growth, fertiliser applications, animal live-weight gains and optimal stocking rates, and pest and disease management.

3.10.1 Benefits of using seasonal climate forecasts in agricultural adaptation

Seasonal forecasts have great potential to support farmers' decisions making about agricultural management. In fact, Ziervogel *et al*. (2010) noted that in livestock farming, the use of seasonal forecasts is actually a valuable adaptive strategy used for addressing erratic climate. Marshall *et al.* (2011) note that studies have indicated that seasonal forecasts have a significant role in safeguarding farming against climate variability such as the El Niño and La Niña or high variability in seasonal rainfalls. For example, these seasonal forecasts offer graziers the prospect of adjusting stocking rates ahead of any catastrophic climatic event (Marshall *et al*., 2011). Hence, farmers that use this approach can take advantage of the wet years and limit damages during the dry years (Ziervogel *et al*., 2010). Studies from Southern Africa by O'Brien *et al*. (2000) indicate that seasonal forecasts can assist in increasing food security but to optimise potential benefits, dissemination and response strategies need to be developed. These seasonal forecasts provide livestock farmers opportunities to make well informed decisions which ultimately increase their climate change adaptive capacity (Ziervogel *et al*., 2010).

3.10.2 Barriers to seasonal forecast use in agricultural

A study by Marshall *et al*. (2011) observed that in-spite of the potential benefits of using climate forecasts, few farmers use them for adaptation. A number of key barriers to the use of forecasts by famers have been identified (Shankar *et al.,* 2011), and such barriers are outlined below:

(i) *Forecast reliability* - A vast study, covering over 2500 farmers, from Australia revealed that the reliability was identified as the key reason (about 76% of the respondents) constraining the utilization of forecasts (Agriculture Fisheries and Forestry Australia as cited in Shankar et al., 2011). These findings were consistent with other studies (for example, Manatsa *et al.,* 2012; Jochec *et al.,* 2001) that demonstrated that climate forecasts accuracy must be about 75% for it to be acceptable to farmers.

(ii) *The perceived lack of skill or capacity of the farmers:* The farmers must have the capacity and willingness to change behavior.

(iii) *Effective dissemination and communication of forecasts*: The acceptance of forecasts and related agro-meteorological information depends on effective distribution and transmission of sector specific forecasts. These findings were consistent with other studies by Manatsa *et al*. (2012) that observed that the distribution process of forecasts is very complicated, resulting in the late and distorted reception by farmers.

3.10.2.1 <u>Methods to overcome barriers to uptake of forecasts in agriculture</u>

Wilk *et al*. (2017) state that for forecasts to serve as early warning systems used to adapt to climate change, such systems need to be coordinated with national drought and climate change strategies that concentrate on risk management and early warning systems. In essence, if farmers are to make well-timed decisions, avert disastrous situations, and increase yields, they must be competent in using the forecasts to ensure they prepare for and mitigate negative outcomes. If not, then climate forecasts will only serve as a crisis management approach towards climate change management, and not enable more transformative processes that decrease vulnerability of smallholder farmers and enhance food sufficiency.

Notwithstanding the barriers of climate forecasts Hansen *et al.* (2011) mention that there are a number of opportunities for supplying beneficial climate data to agriculture. Such options include: the downscaling of seasonal forecasts onto available stations; the inclusion of pertinent and foreseeable data about "weather-within-climate" like enumerating rain days; including probabilistic forecasts of impacts on forage or crop yields that are revised throughout the cropping period.

Marshall *et al*. (2011) state that livestock farmers need to be encouraged on the economic and environmental benefits of forecasts. While Hansen (2002), Meinke and Stone (2005) and WMO (2010) elaborate on this observation by stating that forecasts should fulfil a number of criterion to be important to agriculture, and such includes having economic benefits (farmers must be convinced that when using forecast information effectively they will be better off than before); they must build resilience; they must be fairly correct and appropriate for their utilisation; and the forecast evidence has to be plain and realistic. These forecasts should focus on the key variables needed to make adaptation decisions. Lastly, these forecasts must have ample turnaround time to ensure that the users have sufficient time to implement adaptation options. This observation for applications is promoted by a study by Mase and Prokopy (2014) that highlights the potential value of increasingly sophisticated and accurate weather and climate forecasts.

3.10.3 Studies on use of climate forecasts for adaptation

Marshall *et al*. (2011) examined the rationale for poor taking up of seasonal forecasts by livestock farmers for handling climate variability in north-east Queensland, Australia. A total of 100 farmers were surveyed, whereby the effect of adaptive capacity, resource-dependency, and forecast-awareness were examined to determine their influence on uptake of climatic forecasts by the livestock farmers. The results provided that leadership skills, environmental awareness and social capital were important for the uptake of seasonal forecasts. Social factors significantly influenced uptake. These findings are valuable for building resilience and adaptation amongst communities reliant on climate-sensitive resources. The study by Marshall *et al*. (2011) suggested that the promotion of the economic and environmental benefits of seasonal forecasts might considerably improve their acceptance.

While a recent study in India by Nidumolu *et al.* (2020) was conducted to discover means to overcome obstacles to useful distribution, communication, and utilisation of seasonal climate forecast on the farm and throughout its production chain. The methodology used was a case study approach. The findings of this study concluded that effective social networks perform a key function in deciding favourable prospects and restrictions to useful distribution and communication of seasonal climate forecast to farmers. Secondly, the incentive to use seasonal climate forecast was different throughout the production chain where it was less used by small off-farm production chain actors, but was of greater value to bigger production chain players who had a better understanding of how seasonal climate forecasts assist in decision making (Nidumolu *et al*., 2020).

In the same way, Hansen *et al.* (2011) reviewed the use of seasonal forecasts in agriculture in African states in order to appreciate their use and to seize possibilities to recognise future services. In their review, it was observed that widespread uptake of seasonal climatic forecasts was constrained, thus, the possible uses of these are not realised mainly as a result of extensive communication difficulties. This is in spite of the considerable progress made by many national meteorological services in making forecasts easily available to farmers across various outlets. The main reason for lack of uptake is that farming does not have an active say on climate information services, thus, forecast material and related aids are improperly designed for agricultural requirements (Hansen *et al.,* 2011).

Similarly a study by Rasmussen *et al.* (2014) explored how farmers in the Sahel region responded to climate information they received in 2013. The study aimed to evaluate whether forecast information provided matched with the actual needs of pastoralists. The results showed that a small number of farmers received the seasonal forecasts. The farmers with access to the forecasts used them to adapt crop farming approaches in preference to livestock farming strategies. The study revealed that for the farmers to adjust their livestock management decisions they needed additional information relating to the timing of rains, flood events, and spatial abundance of grazing. These facts would assist make changes in herd composition to make suitable decisions on migratory herding destinations, and to inform the purchase of extra feed. The farmers who reacted to climate or grazing information by using various adaptation approaches acquired climatic forecasts. The information was generally obtained from family and friends as opposed to formal organisations. Lastly, there was a wide gap between farmer information needs and what was provided (Rasmussen *et al*., 2014).

On another note, a study in Senegal by Roudier *et al*. (2014) evaluating the use of forecasts in agriculture, used a participatory research approach. The approach made use of simulation exercises including the use of simulated forecasts information. Based on these, the farmers made adjustments to farming methods for above three quarter of all the cases. The method changes were grouped into either suggesting non-intensified strategies (31%), or pure intensification strategies (21% of cases), or mixed strategies (24%). The harvest approximations concluded that using forecasts increased harvest by 33%, with somewhat few losses. The findings validated previous studies that suggested that climate forecasts could assist Senegalese farmers adapt to climate variability.

According to Oladele *et al.* (2018), in a study evaluating the use of agro-weather data for climate resilient farming in Kenya and Ethiopia, it was revealed that a farmers' knowledge and the influence of forecasts data were substantial reasons to use climate forecasts, while excess to extension support by the farmers was a major determinant of the farmers' use of platforms (for example, SMS, newsletter, and radio) on which agro-meteorological information is available. The significance of these variables stressed the need of policy on tools for the use and distribution of forecasts.

At a regional level, Manatsa *et al.* (2012) investigating the uptake of the convectional seasonal forecasts hand-out, through the SADC climate outlook, is very low, mainly due to "poor forecasts" and inadequate lead times in the forecasts. For example, in Zimbabwe, the periodic droughts are never in forecast, and the bias towards near normal conditions is almost perpetual; hence, the forecasts are poorly valued by the farmers. Secondly the dissemination process of these forecasts is also very complicated, resulting in the late and distorted reception. Thirdly, the probabilistic nature of the forecast makes them difficult for interpretation by the farmers. The likelihood of farmers benefiting from these seasonal forecasts is subject to their flexibleness and preparedness to adapt agricultural activities to the forecast (Unganai and Kogan 1998 in Manatsa *et al*., 2012).

A study by Kgakatsi and Rautenbach (2014) focusing on the use of seasonal climate forecasts (SCF) information in South Africa, after the assembling and distribution of early warning data, aimed at reducing risks faced by farmers. It was noted that SCF information is generated by the scientific community and distributed to the farmers via agents. The results of this study emphasised ways to strengthen and improve early warning systems in the agricultural sector in order to avert and lessen the effects of climate change. Furthermore, it provided a basis of how to improve the early warning approach. The study by Kgakatsi and Rautenbach (2014) concluded that an improved early warning approach should have the following features to be effective and innovative:

(i) A seasonal climate forecast information feedback programme should be implemented to improve all features of the early warning systems i.e. knowledge, prediction and warning service, dissemination and communication, and response;

(ii) To improve dissemination and communication of SCF information end user analysis need be undertaken.

(iii) Seasonal climate forecast producers must package information according to the needs of the targeted audience;

(iv) The Government must develop policies that will ensure compliance within the agricultural sector in implementing early warning systems.

3.10.4 Methodologies used to evaluate use of forecasts for adaptation

A study in west Texas conducted by Jochec *et al*. (2001) using a FGD of ranchers that consisted of seven members from commercial-scale ranchers, who were selected based on their willingness to participate in a technology development and implementation study. The group was presented with climate forecast information and the probable impacts of different climate conditions on forage production. After discussing the probabilities and risks associated with the forecasts, the ranchers were asked to evaluate the stocking-rate decision rules to see what changes, if any, would be made after the forecast information is considered. Forage production and livestock performance were simulated by the Phytomass Growth simulator (PHYGROW). Results from the PHYGROW were used in an economic model of net returns per section. The net returns obtained using the base and revised decision rules were used for assessing the economic implications of using forecasts. Initial results were presented to a second reconvening of the focus group. The group's reactions were that current forecasts are too uncertain and cover regions that are too broad; hence, forecasts need to be more site-specific and accurate to be incorporated into their management practices. Furthermore, the forecasts must be about 70-80% correct and have a five year track record before the ranchers would be satisfied to utilise them. Lastly, the time of receiving the forecasts must be such that it allows the farmer to make adjustments.

However, Oladele *et al*. (2018) state that the methodology used in the study evaluating the use of agro-weather data for climate resilient farming in Kenya and Ethiopia, is as follows: The population of the study had access to agro-weather tools which included: newsletters, radio, and SMS in Ethiopia for farmers who farmed coffee, tea, beans, sorghum and maize. From these farmers, a sample was drawn using both systematic and random sampling techniques. The sampled farmers in Kenya were 360 farmers while in Ethiopia there were 171 farmers. The sample size was derived using the Raosoft sample size calculator. A structured questionnaire was used to collect data, and it was analysed using the Statistical Package for Social Sciences (SPSS) version

21.0. Both descriptive and inferential statistics were utilised on the data, and multiple regression was utilised to identify the factors influencing the use of agro-weather tools.

The regression equation/model is as follows:

$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots\ldots\ldots\ldots \beta_n X_n + {}_e$

Where Y is the use of agro-weather tools (Radio, SMS, Newsletters, measured as use on an acceptance scale, the X's are the predictor variables, while the β's (i.e. betas) are the unknown parameter vectors and e is the error term.

On the contrary, a study from Ghana by Villamor and Badmos (2016) developed a role play game called the "Grazing Game," and used it to explore whether Role Play Games can assist learning between the game implementers' and the game target participants, or players being the farmers from multiple sites in Ghana. The grazing game was developed to show how games can result in improved perception of farmers' resilience to climate change in a dynamical and co-operative approach. To demonstrate this hypothesis, the following questions were explored: (1) How do games enable public and expected learning? (2) What awareness, for example, managing strategies, capabilities, or changes in knowledge of the actors are produced using the games? The method followed was developing a role play game called Grazing Game which was an altered form of "Overgrazing Game" created by Van Noordwijk (1984). In their case, Villamor and Badmos (2016) adapted the game to suit their research aims. This version simulated dry land conditions for farming that is heavily reliant on rainfall as well as aspects which added versatility and difficulty into the game. The conceptual model of the modified game is illustrated in Figure 3.1. The actors, namely: the farmers and market resources being rainfall, cows, grass, land patches; and the processes are reproduction and regrowth of grass; and strategies, such as sell the cows, keep the cows, or locate the cows on hills or to the valley. The simple progressions in the game involved a grass growth cycle that is founded on rainfall; for example, little rain restricts grass development, and extra rain escalates grass growth and cow breeding. The resources conceived in the model are pointers to be observed, such as amount produced, amount sold, and increases in herd size. The arrows showed in Figure 3.1 define the connections between determinants and consequences, comprising simple decision strategies; for example, selling cows, keeping cows, and grazing management.

The results of the study showed that the farmers displayed positive response to current rainfall fluctuations experienced, and this resulted in the recognition of managing plans, such as culling cows, looking for government support, and engaging in different sustenance earnings. Secondly, the involved farmers had a tendency of avoiding unclear conditions and tried to clarify their choices. The game also revealed that the farmers had abundant native information of ecological indicators. Thirdly, the results showed that the game facilitated progressive and communicative learning amongst the actors and implementers. Lastly, the game aided as a forum where the farmers can exchange opinions, information, and views of climate-linked matters (Villamor and Badmos, 2016).

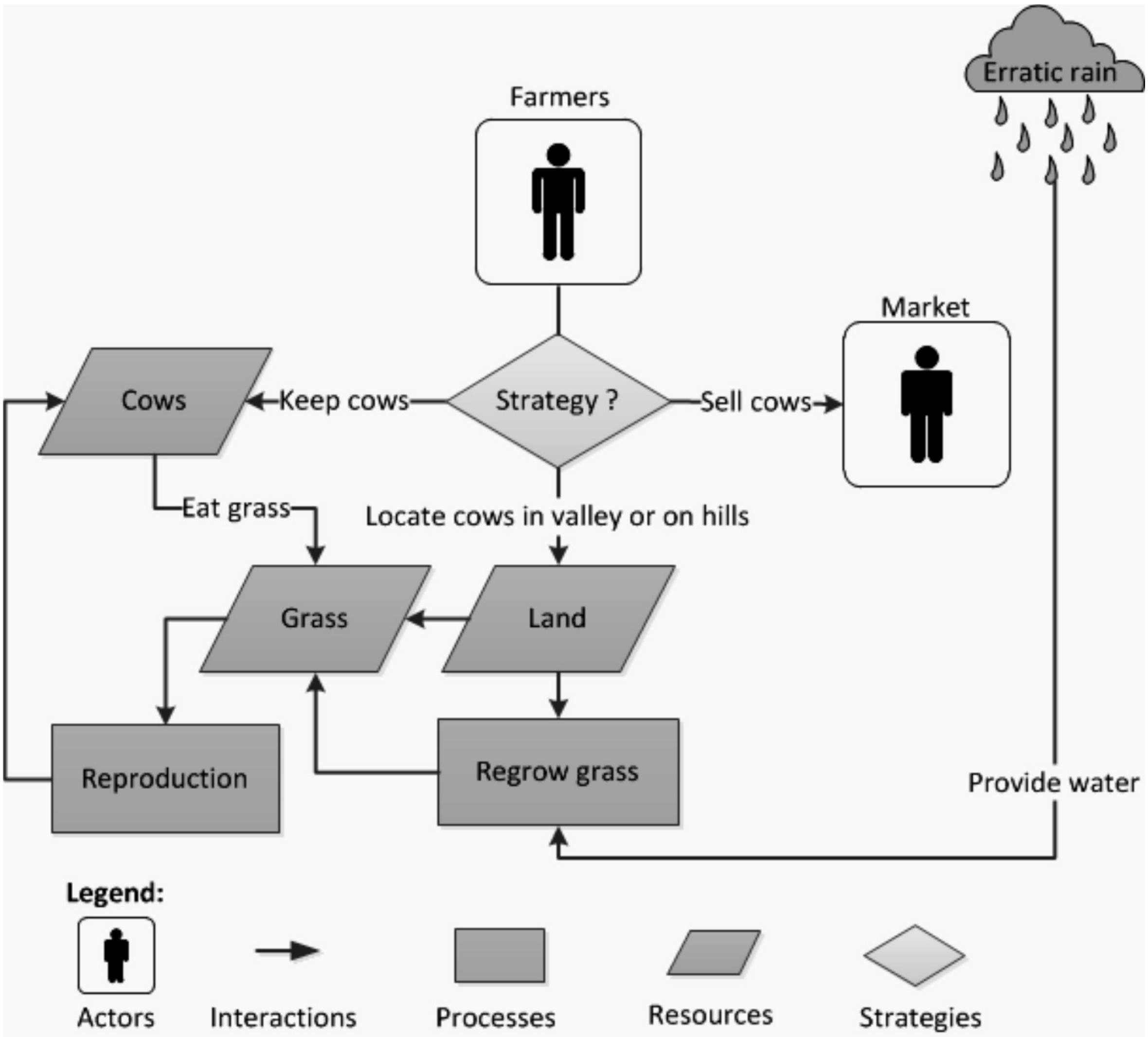


Figure 3-1: Conceptual model of the grazing game, (Villamor and Badmos, 2016).

Another study from West Africa - Senegal by Roudier *et al*. (2014), evaluating the use of climate forecasts in small scale farming using a participatory research approach, addressed the questions relating to farmers' use of forecasts in crop farming, and if the adaptations made attained benefits.

In this participatory approach, farmers were engaged using imitation farming to obtain the crop farming approaches under different (simulated) climatic conditions. The aim of this exercise was to observe the farmers adaptation strategies to different climate forecasts. The participatory workshops approach integrated local and scientific knowledge systems. Two communities were used in the study, and the participatory workshop was held in each community to investigate the farmers' use of the forecasts. A sample of 16 farmers from each community was used in the workshop, but eventually only 12 and 13 farmers completed the exercises. During the workshops the farmers were provided with seasonal forecasts plus supplementary material to explain these forecasts. Based on this information, farmers had to simulate operations on their farms till harvest, and also to estimate their harvest based on the adaptations practices they chose in line with the forecast (Roudier *et al*., 2014). In closing the workshop, most of the farmers indicated that they were confident in the use of forecasts as an adaptation tool as they were considered as a valuable tool to assist them with the selection of crops varieties.

At a regional level, O'Brien *et al*. (2000) investigated small-scale farmers' utilisation of seasonal forecasts from three countries (Namibia, Tanzania and Zimbabwe) in southern Africa) where the study investigated how and if farmers obtained, utilised, and understood the forecasts for a farming season. The methodology followed made use of two surveys to determine the extent to which the seasonal forecasts reached end users (small scale farmers). Their reactions specified how forecasts could enhance farming output. The survey interviews were conducted in key agencies or organisations from all countries. These interviews gave the bigger picture on the current or prospective utilisation of the forecasts in these countries. Secondly, content analysis of articles in the press before and throughout the growing season were done to determine forecasts' distribution.

3.11 Research Gaps and Needs

Even though research on climate change impacts and adaptation in livestock farming is generally increasing a number of research gaps were identified, some of which the study will attempt to address and these are outlined below.

Porter *et al*. (2014) and Thornton and Herrero (2015) affirm that much research on climate change and its impacts has been done, particularly on cultivated agriculture and considerably less research has been done on climate change impacts on livestock farming systems. At a continental level, particularly in sub-Saharan Africa a number of studies have been carried out on climate change and its impacts on pastoralist farmers, mainly in the drier regions. At a regional level some studies on the subject have been conducted, while at the local level, in Eswatini, a very few localised and exploratory studies indicated that livestock production is impacted by climate change (e.g. Manyatsi *et al.*, 2010; Nkondze, et al. 2013). The study by Manyatsi *et al.* (2010) focused on mixed farmers' perception of climate change whilst that by Nkondze *et al.* (2013) focused on farmers' perception of the impacts of climate change and livestock health and only covered one of fourteen constituencies (Tinkhundla Centres) in the Lowveld. None of these studies focused on the adaptation approaches employed by the livestock farmers.

While reviewing the literature on climate change trends it was evident that climate was changing and a number of studies have been carried out at global, regional and country level. However limited climate trend studies were carried out for parts of lowveld of Eswatini, these trend studies either focused on temperature and or rainfall (e.g. Manyatsi *et al.*, 2010) or extreme events such as droughts (e.g. Mlenga *et al.,* 2019; Tfwala *et al.*, 2020). However, there was no record of an in-depth study on climate trends that included seasonal climate trends, in the area to determine if and how the climate had changed.

How farmers perceive climate, is widely studied within the country, but mostly in relation to crop farming (Oseni & Masarirambi, 2011; Mamba *et al.*, 2015). In the lowveld region localised studies on livestock and mixed farming systems were done by Manyatsi *et al.*, (2010) and Nkondze *et al.* (2013). However there is no evidence of livestock farmers' perceptions covering the whole region. Similarly the approaches and strategies used by livestock farmers for adaptation to climate change impacts have been studied at a regional and local level. At the local level an extensive adaptation study was conducted on maize farmers by Khumalo, (2018). However with regard to livestock farming, very localised (covering one of the 14 constituencies) studies were carried out by Manyatsi *et al.* (2010) and Nkondze et al. (2014) with no in-depth study on climate change adaptation for livestock farming for the lowveld of Eswatini.

The use of early warning systems such as seasonal forecasts as a tool to assist livestock farmers with climate adaptation has gained significant attention globally and regionally. In sub-Saharan Africa, especially the Sahel region, seasonal forecast are used by pastoralist for climate change adaptation. In southern Africa and Eswatini the use of seasonal climate forecasts is mainly by dry land crop farmers. Research of their use in the region by livestock farmers is very rare (Archer *et al.* 2021 in South Africa and no such study could be found for Eswatini.

The literature also indicated that climate adaptation policy evaluation has gained popularity and attention at both the international and local level. At international level there are global conventions on climate change that have sections devoted to adaptation, while at national level, countries in the region have domesticated international adaptation policy plans into development frameworks and every country reports on how it has implemented these policies. The review indicated that most this policy formulation used a top-down approach, with little or no participation from the community. There was therefore a need for research on including bottom up approaches to policy evaluation.

These are just a few research gaps that were discovered during the review of literature. Given that a study to address most the gaps would be exploratory, further gaps would be revealed by the outcome of the study.

3.12 Conceptual Framework

The conceptual framework for this study (Figure 3.1) stems from the understanding that climate change affects livestock farming through droughts, floods, grazing availability, and the farmer in general. Such affects result in impacts that disturb the productive and reproductive capacity of livestock, these impacts could be in the form of one or a combination of the following; increased mortality, low birth rates or reproductive capacity, reduced growth, increased incidence of sickness and diseases and reduced milk production. The impacts on the livestock farmers' livelihood can be through diminished incomes from milk or livestock sales which reduce the income the farmer use for their livelihood activities.

The effects of climate change and impacts on the farmers can be an area of concern for external participants (outside the farm) and such could include government departments, markets, research institutions, NGO's, banks, etc. These institutions could also be sources of information on climate change, its impacts and tools to assist with adaptation for example long term forecasts to assist with adaptation, or provision of drought tolerant breeds by government or improved range management.

Climate change, its effects and impacts influence the farmers' perception about climate change, this perception is also influenced by external factors such as information and assistance received from government, NGO's, markets, etc. The perceptions of the farmers about climate change and its impacts on their livestock farms and households can be either accurate, or under estimated or incorrect. The adaptation strategies used by the farmers can be grouped into behavioural, managerial and technical strategies. The choice of use of adaptation strategies can be influenced by the farmers' perception as well as information or support received by from external forces. Furthermore the farmers' level of vulnerability, their internal factors (such as experience and level of education or training, etc.) can also influence the choice of adaptation strategies employed.

The farmers can also make choices to either implement the adaptation strategy or not implement it. Meaning they can either adapt their farming or not adapt to the impacts of climate change. If they adapt they minimise their vulnerability to climate change impacts and if they do not they increase their vulnerability to climate change impacts. The farmers' ability to adapt can be a measure to their level of vulnerability to climate impacts.

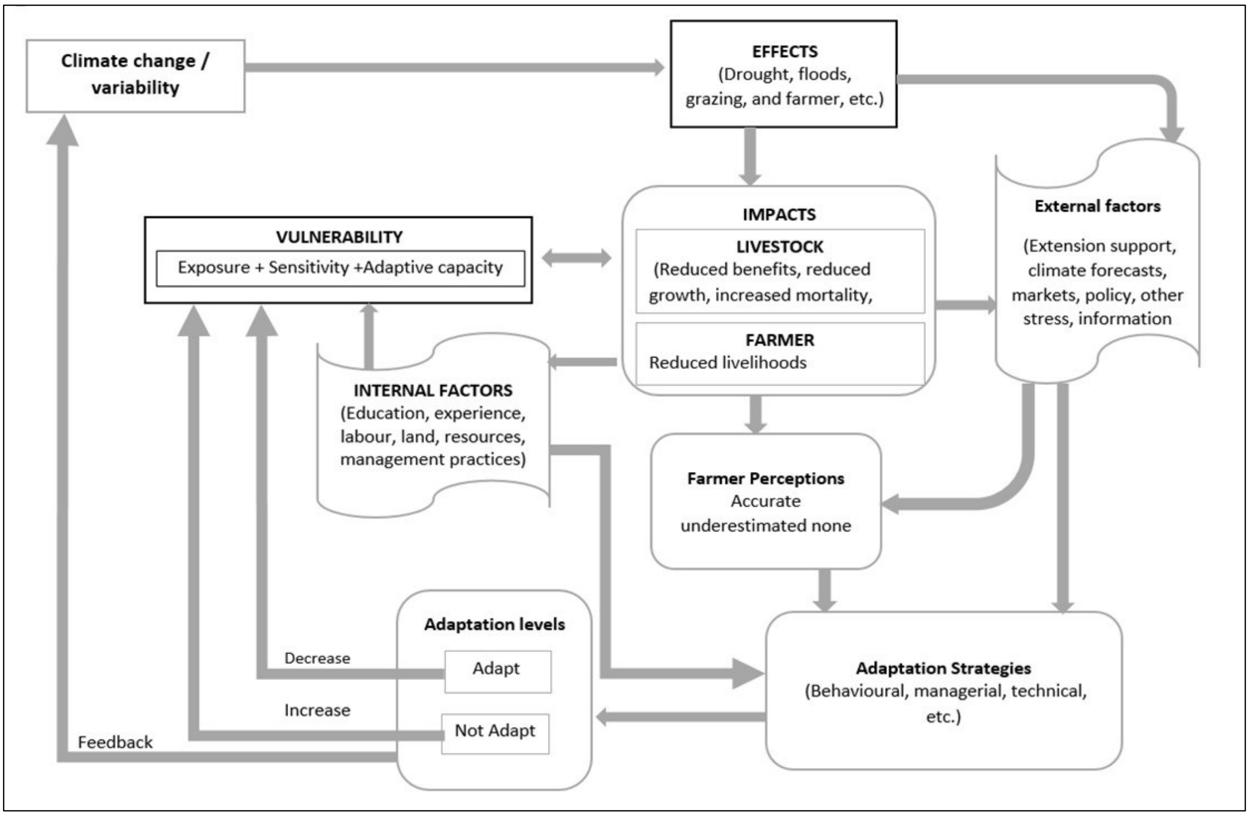


Figure 3-2: The conceptual framework

Source: adapted from Turner et al. (2003) and Abid et al. (2019)

3.13 Conclusions

In context, this chapter discussed the reviewed literature against the backdrop of the impacts of climate change on livestock farming and how the farmers comprehend climate change and adapt to the associated impacts. This chapter started by reviewing literature from the causes of climate change where livestock farming is another leading cause, through to an understanding of the theoretical concepts of the impacts of climate change on the environment and a consideration of its impacts on agricultural systems as a whole, through to its eventual impacts on the livestock systems. From this review, it became apparent that climate change affects the environment and these effects cascade to farming systems such as cropping systems that are relient on rain water, and eventually these have a bearing on livestock systems in many ways such as provision of grain for food or supplementary grazing from crop stover.

To ensure validity of the study, the literature reviewed highlighted the need to determine or prove if there was an actual change in climate in the study area, and the methods used to determine climate change are the use of trend analysis of climatic records. Subsequent to the literature review on trend analysis was a review of literature on understanding livestock farmers vulnarability to climate change, linked to vulnarability is the farmers adaptive capacity, where low adaptive capacity tends to lead to vulnarability amoungst the farmers, and high adaptive leads to reduced vulnarability to climate change. Futhermore, methods used to measure and reduce vulnerability amongst livestock farmers were also reviewed, together with approaches used to assess climate change vulnarability.

A review of literature was done for farmers' perceptions of climate change plus the different approaches used by scholars to analyse farmers' perceptions to climate change. Such methods include: Descriptive Statistics, Multinomial Logistic Regression Model, Moran's I Test for spatial autocorrelation and simply comparing farmers observations of climate to meteorological data to determine if their perceptions could be correlated with actual data. Linked to perceptions, was reviewing publications on climate change adaptation, and how livestock farmers around the world, as well as in the region, were adapting to climate change impacts. The methodologies used to analyse farmers' adaptation to climate change along with methodologies to determine the factors affecting the farmers' choice of adaptation were also reviewed. In summary these methodologies included: the Descriptive Statistics, the use of Pearson's Chi Square, the use of inferential statistics (Multinomial Logit models), as well as Moran's I Test for spatial autocorrelation.

Climate change adaptation is also a result of a country having a conducive climate change adaptation policy. Thus, this review also focused on climate change adaptation policies and their evaluation. One of the generally used methodologies for climate change adaptation policy evaluation was Qualitative Document Analysis and Content Analysis, such a methodology could be enhanced with a Bottom-up approach. This approach allows the farmers to provide input to policy issues government could implement to assist them adapt to climate change impacts. An adaptation option used to assist farmers to adapt was the use of technology or forecasts. Climate forecasts and projections are information available to the farmers to help them with on-farm decision making. The study also looked to determine how the farmers used forecasts and how long term forecasts and projections would influence their decision making. Thus, the literature indicated that there are various methods that can be employed to evaluate this; and one method chosen for the study was the use of simulation exercises using a participatory approach with the farmers to determine their various adaptations.

In conclusion, the literature reviewed indicated that livestock farming was lagging behind cropping systems in agriculture with respect to climate change adaptation research. Since livestock farming is affected by a more complex interaction of climate and the ecosystem in which farming takes place as opposed to crop farming, a deeper understanding of this system is vital to ensure adaptability in the long run. Thus, the methods reviewed for analysis were anticipated to provide a better understanding of the impacts of climate change and adaption by livestock farmers in the study area, the Lowveld of Eswatini as well as provide the conceptual framework which would assist in guiding the study.

CHAPTER 4

METHODOLOGY

4.1 Introduction

This chapter addresses the techniques and procedures which were applied to obtain the data required in the study and enable the answering of the research problem. Items that are addressed in the present chapter include the: research design, research method, sampling, data collection instrument, data analysis method and ethical considerations of the research.

4.2 The research approach

The research approach employed in this study was a mixed-methods approach. According to Creswell (2014:31) the mixed-methods research "is an approach to inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs. The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone".

4.3 Research design

Kothari (2004) indicated that a design deals with decisions regarding the what, where, when, how much, and by what means of a research study. The research design is "In fact, the conceptual structure within which research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data" (Kothari, 2004:31). Creswell (2014) states that during research, the researcher not only decides on the research approach for the study but also on the type of research design within the chosen approach. A summary of research designs available within each choice are listed in Table 4.1.

Table 4-1: The Research approaches with their associated designs

Quantitative	Qualitative	Mixed Methods
• Experimental designs • Non-experimental designs, such as surveys	• Narrative research • Phenomenology • Grounded theory • Ethnographies • Case study	• Convergent • Explanatory sequential • Exploratory sequential • Transformative, embedded, or multiphase

Adopted from Creswell (2014)

Within the mixed methods approach the study used the explanatory sequential research design. According to Creswell (2014), the explanatory sequential research design is a mixed method, where the scholar firstly performs quantitative research then analyses the data and results. Then builds on the results by explaining them in greater detail using qualitative research. Thus, it turns out to be explanatory since the primary quantitative results are further rationalised using qualitative data. The design is also deemed sequential since the first quantitative phase is followed by a qualitative phase (Creswell, 2014).

To collect the quantitative and qualitative data the survey research method was used. Surveys are mainly used in studies that have large units of analysis where data describing a population is too large to observe directly (Kothari, 2004; Creswell, 2014). According to Saunders, Lewis and Thornhill (2000), the survey is the most common strategy used to collect research data. This is because surveys permit the gathering of large amounts of data from a large population in a cost-effective way. In the survey method, the respondents answer questions delivered using interviews or questionnaires. Typically, surveys try to explain what is happening or study the cause for a specific activity; hence, most of them are descriptive research (Zikmund, 2003). Also, typical survey objectives are meant to identify the attributes of a specific group, measure attitudes and describe behavioural patterns (Zikmund, 2003). Furthermore, surveys can either be cross-sectional in nature or longitudinal studies (Zikmund, 2003; Creswell, 2014). The study uses a cross-sectional design, by which the respondents are investigated or observed at one point in time. In this study, the survey research method will be used as the main method to collect data from respondents using a questionnaire as an instrument of data collection.

4.4 The population and sample

For this study, the population was all livestock farmers in the Lowveld of Eswatini. The estimated population size, based on 2017 livestock census data for livestock farmers was about 10776 famers, who owned about 105519 cattle (Ministry of Agriculture, 2017). However, since studying all farmers was impossible due to time and financial constraints, sampling was conducted to get a representative sample of the farmers.

4.4.1 Population sampling design

In an effort to ensure that the coverage of the participants is reflective of the Lowveld of Eswatini, a multi-stage area sampling design was used. According to Kothari (2004), area sampling is similar to cluster sampling, and is often used when the total geographical area of interest happens to be a large one. In area sampling, the total area is first divided into a number of smaller non-overlapping areas also known as geographical clusters. If this method is done on a multi-stage, it is called a multi-stage sampling, whereby the sample can be chosen from a region, then to a smaller area; for example, from a district to towns in the district, and finally, sampled families within the towns. Wherein this random-sampling is applied at all stages, the sampling procedure is termed as multi-stage random sampling (Kothari, 2004).

4.4.2 Sample selection

This study made use of multi-stage area sampling to identify and select the research participants, a similar sampling methodology was used by Kgosikoma *et al.* (2018) while studying the determinants of climate change adaptation among agro-pastoralists in Botswana. The sampling for this research was conducted in the following manner: firstly, the lowveld extends over 14 local constituencies (administrative areas) called Tinkundla, namely: Mhlangatane, Mandlangempisi, Mhlume, Mkhiweni, Dvokodvweni, Gilgal, Siphofaneni, Mpolonjeni, Nkilongo, Sithobela, Lubuli, Sigwe, Somnthongo and Matsanjeni (*Figure 4.1*). From the 14 constituencies, a random sample of 10 constituencies were selected (this equates to a margin of error of 10%, confidence level 70% and sample proportion of 50%) using an online random sample calculator by Raosoft, (Raosoft, 2004). The constituencies selected were Mhlangatane, Mandlangempisi, Mkhiweni, Dvokodvweni, Gilgal, Siphofaneni, Mpolonjeni, Sithobela, Somnthongo and Matsanjeni (*Figure 4.1*).

From these chosen constituencies, random sampling was utilized to choose the sample of farmers from the lowveld livestock farmer's population. The farmers' population was 10776 and the population sample was calculated with the online sample calculator Raosoft (Raosoft, 2004). The sample size was determined using the following criteria: The margin of error used was 5%, the confidence level was 90% and sample proportion of 50%. Based on the above criteria the minimum sample size was 266 livestock farmers. This equates to about 26.6 farmers per constituency which was rounded-off to 30 per constituency, and 278 farmers responded from a total of 300. The 278 is slightly larger than the minimum recommended sample size.

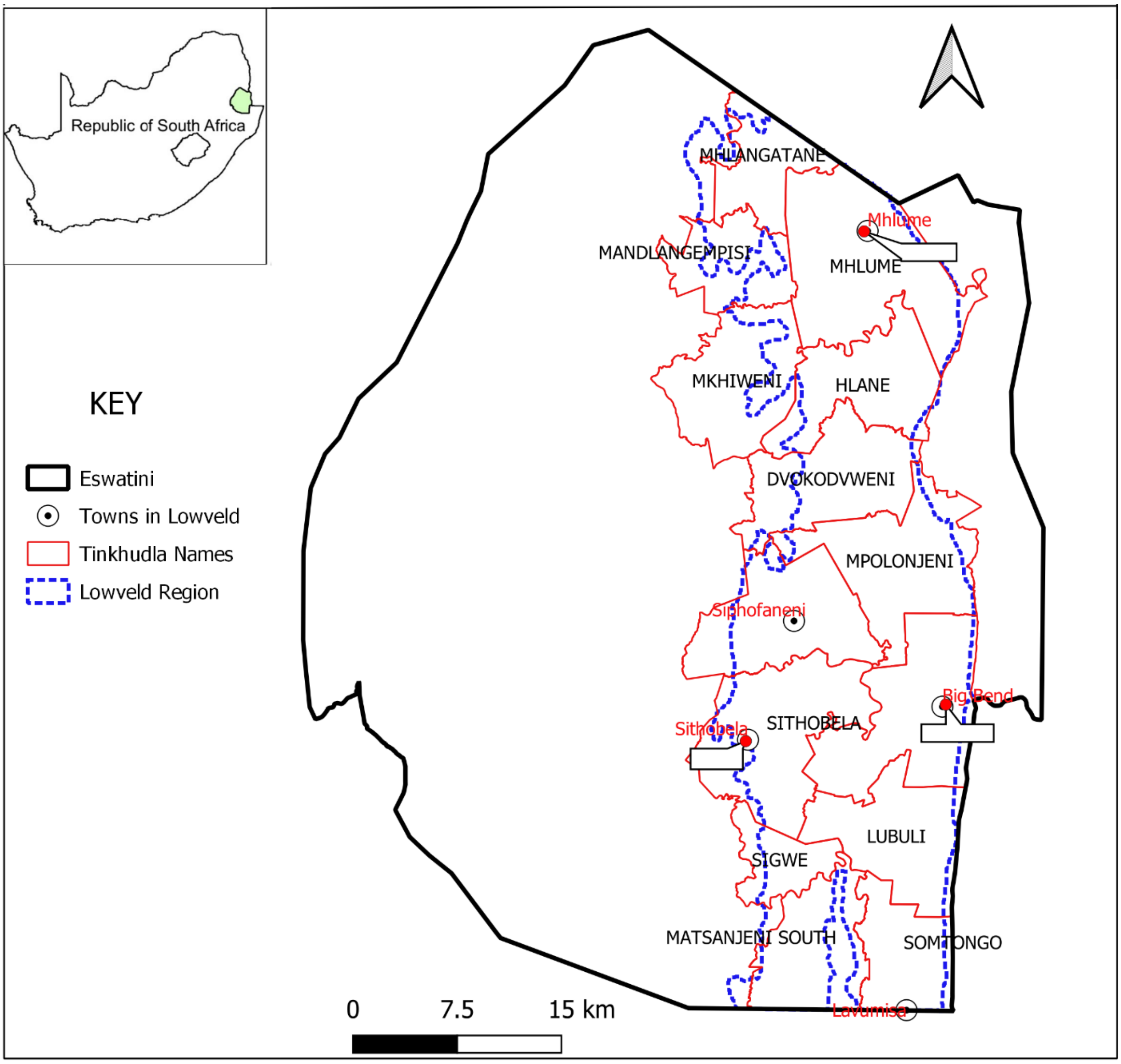


Figure 4-1: Map showing Tinkundla and selected towns with meteorological stations

4.5 Types of data used and data sources

As outlined in the section on the research design, the study employed the explanatory sequential research design, which uses quantitative research which requires the analysis of quantitative data, and then uses qualitative data to explain any observed results in detail. Therefore, the data collected for this research was qualitative and quantitative in nature. Secondly, the data used included primary and secondary data. The primary data was mainly sourced from the farmers (respondents) using a structured questionnaire that was complemented by data obtained from key informant interviews. Initially the study intended to use focus group discussions (FGDs) and participatory discussions to collect data; however, due to restriction on people gatherings due to COVID-19, these discussions were held with key informants from the communities. Secondary data, that included meteorological data as well as policy documents, was obtained from the meteorological services and government website respectively.

4.6 Data collection Instruments

Data collection is a precise and systematic method of gathering information relevant to the research purpose, or of addressing research objectives and research questions (Burns & Grove 1993). Various methods exist that are used for data collection. In this study various data collection instruments were used to collect both the primary and secondary data required by the study.

A combination of data collection instrumentation were employed to collect data. These included an arrangement of primary data collection instrumentation involving a household questionnaire survey, a semi-structured key informant interviews guide and content analysis to gather data from policy documents. The secondary data instrumentation included tools for the collection and review of various policy documents. Also planned for the study was the use of focus group discussions and as an instrument for collecting certain data, however due to Covid-related restrictions on gatherings this instrument use not possible.

4.6.1 Primary data collection Instruments

For the study, most primary data was collected through a survey that made use of personal interviews. The personal interview method was applied to household heads and required the researcher to ask questions in face-to-face contact with the respondent (Kothari, 2004). The questions asked were in the form of a structured questionnaire. The questionnaire survey was adopted in this study because it was cost effective and allowed for collecting a lot of information in a short period of time, furthermore structured and standardized nature of the questionnaire tends to yield high response rates.

Primary data was also collected using key informant interviews. For these interviews semi structured questions were utilised to solicit details about adaptation choices based on projected forecast and climate change projections. The key informants interviews were employed because the data was gathered from knowledgeable persons who could provide insight that could not be obtained with other methods. In addition they provided flexibility, to allow the exploration of new issues related to the subject. Key informant interviews are also cost effective method of gathering data.

Lastly primary data was collected using content-analysis to gather data from policy documents. Content-analysis consisted of analysing the contents of documentary materials such as books, policies, reports, magazines, etc. (Kothari, 2004). The Content-analysis used in the study was generally quantitative, where certain characteristics about climate change policy documents were identified and counted. Content analysis was used to analyse policy document because it was relatively cheap to use and has a high reliability as it followed a systematic procedure to be replicated.

4.6.1.1 Components of the questionnaire

In the development of the questionnaire, previous researchers' questionnaires on similar studies were used as guidelines for formulating the questionnaire (De Klerk, 2001; Feldman, 2002; Sango, 2013; Elia, 2013). Additional relevant questions were included. The questionnaire consisted of five sections, where Section 1 sought bibliographic information of the respondents. Section 2 addressed climate change knowledge of the respondents. Section 3 addressed climate change observations and experience of the respondents. Section 4 sought information on climate change adaptation methods used by the respondents. Finally, Section 5 consisted of questions that seek to find out the costs and income from livestock production from the respondents (see Appendix 1).

4.6.1.2 The key informant interviews

The key informant interviews a guide with questions were utilised to solicit the informants' views on climate change impacts (see Appendix 2), and the methods or approaches applied to adapt to climate change (to address objective one, two and four, respectively). Their views on long-term climate forecasts and climate projections, as well as, how these forecasts or projections can assist in climate change adaptation, were solicited (mainly to address objective three).

4.6.2 Secondary data collection

Secondary data means data that are already available or data which have already been collected and analysed by someone else (Kothari, 2004). The secondary data collected in this case was unpublished climatic data obtained from the Department of Meteorology in Eswatini. The benefits of using secondary data in this study, related to the benefit that it helped in improving the understanding of the problem because it provided a basis for comparison for other data collected by the researcher for example it allowed the comparison of long term climatic records with the farmers perceptions.

4.7 Validity and reliability

Since this study has components of qualitative and quantitative research, issues relating to the credibility of the findings crop up. Thus, to ensure credibility of the study, two important strategies, namely: reliability and validity are adopted to enhance the credibility of the research. Radhakrishna (2007) states that validity and reliability tests are two important elements used in the evaluation of the research questionnaire.

4.7.1 Validity

According to Noble and Smith (2015), validity refers to the application and integrity of the methods used to collect data and the precision level by which the research findings correctly reflect the data collected and used, or basically the precision in which the findings accurately reflect the data collected.

For this study, validity was established using experts and a field test (Radhakrishna, 2007). Furthermore, the questionnaire was approved by the supervisor and moderators who approved the research proposal. Following this approval, a field test was conducted using twenty (20) subjects not included in the study sample. After the field test was conducted, minor changes to the questionnaire were made (Radhakrishna, 2007).

4.7.2 Reliability

Reliability is a term used to describe the consistency within the analytical procedures used in the research (Noble & Smith, 2015), and Price *et al.,* (2015) further state that it refers to the consistency of a measure. There are a three types of consistency considered, namely:

(i) the consistency over time (referred to as test-retest reliability),
(ii) the consistency across items (referred to as internal consistency),
(iii) and the consistency across different researchers (referred to as inter-rater reliability).

Reliability tests are conducted to enhance the questionnaire validity, whereby they are concerned with the ability of the questionnaire to measure consistently. To ensure reliability in this study, a pilot test (20 subjects) of results was analysed for Cronbach's alpha. Cronbach's alpha is a numerical coefficient of reliability, or internal consistency of a set of scale or test items. The Cronbach's alpha ranges from 0 to 1, where 0 represents the presence of full error and 1 represents total absence of error. A Cronbach's alpha value of 0.70 or greater is regarded as satisfactory (Radhakrishna, 2007).

4.8 Data analysis

A complex research approach was followed whereby descriptive, associational, and inferential statistics were used to scrutinize the data obtained. The descriptive data analysis was mainly used on the demographic information gathered from the farmers, where the data was summarized into a more understandable format by using averages, frequency distributions, standard deviation, and percentages to show differences between variables; and these results were either presented in tables, charts or graphs. While associational and inferential statistics were used mainly for the perception and adaptation data obtained from the farmers. The main statistical analysis package employed for the bulk of the analyses in this study were IBM SPSS Statistics *Package Release 20.0,* Excel MAKESENS application and *Q Gis version 2.18*. Each data set was analysed using appropriate statistical techniques for the associated objective as informed by other related studies.

Outlined in Table 4.2 is the list of objectives and sub-objectives as well as the data analysis techniques used to achieve the research objectives

Table 4-2: Summary of analysis procedures used in this study per research objective

Primary objectives	Primary Research question	Specific Research sub-objectives	Specific Research Sub question	Analysis Procedure
1. To assess how livestock farming in Eswatini's Lowveld is affected by climate change.	A. How is livestock farming in the Lowveld of Eswatini affected by climate change?	i. To establish if the Lowvelds climate has changed in the last 20-30 years, if so, to what extent.	i. Has the climate of the Lowveld of Swaziland changed in the past 20-30 years, if so, what has been the trend?	i. Excel MAKESENS application- Detecting trends of monthly and annual values (precipitation and temperatures) using the Mann–Kendall test and Sen's slope estimates
		ii. To gather livestock farmers perceptions of climate change and climate change impacts.	ii. What are livestock farmers' perceptions of climate change and climate change impacts?	ii. Descriptive statistics and univariate analysis, multinomial logistic regression model
		iii. To establish how climate change impacts on livestock farmers at the household level.	iii. How has climate change impacted on livestock farmers at the household level?	iii. Multinomial logistic regression model
2. To explore climate change adaptation measures used by livestock farmers.	B. What climate change adaptation measures are used by livestock farmers in the Loweveld of Eswatini?	i. To identify approaches employed by livestock farmers to adapt to climate change.	i. What approaches are employed by livestock farmers to adapt to climate change?	i. Descriptive statistics, the Pearson's chi square, and inferential statistics (Multinomial logit models),
		ii. To determine the factors affecting the choice of adaptation by livestock farmers	ii. What factors determine the choice of adaptation by livestock farmers?	ii. Descriptive statistics, the Pearson's chi square, and inferential statistics (Multinomial logit models
3. To establish if availability of, knowledge of and access to future climate forecasts and projections will influence livestock farmers climate change adaptation strategies.	C. How does the knowledge of, and the availability of access to future climate forecasts and projections influence farmers climate change adaptation strategies?	i. To establish livestock farmers' awareness of available climate information (i.e. climate change forecasts and projections) that could assist them manage their farms better.	i. Are livestock farmers aware of available climate information (i.e. climate change forecasts and projections) that could assist them manage their farms better?	i. Descriptive statistics
		ii. To explore how livestock farmers will react or perceive when information on future climate forecasts and projections are presented to them	ii. How will farmers react or perceive to information on future climate forecasts and projections?	ii. Descriptive statistics and simulation exercises using a participatory approach with the farmers to determine their various adaptations
		iii. To establish livestock farmers' future adaptation strategies based on future climate change forecasts and projections.	iii. What future adaptation strategies would be employed by livestock farmers to deal with future climate forecasts and projections?	iii. Descriptive statistics and simulation exercises using a participatory approach with the farmers to determine their various adaptations
4. To propose policy guidelines that could assist livestock farmers adapt to climate change.	D. What are proposed climate adaptation policy guidelines to assist livestock farmers adapt to climate change?	i. To explore existing policies that could assist farmers with climate change adaptation.	i. What policies exist to assist farmers with climate change adaptation?	i. Qualitative document analysis and content analysis
		ii. To determine policies identified by livestock farmers that could assist them adapt to climate change.	ii. What policies do livestock farmers identify as necessary to help them adapt to climate change?	ii. Descriptive statistics

4.9 Ethical Considerations

As the participants in this research were human subjects, and in order to ensure their rights were protected, the following steps were followed:

(i) Approval of the research including the questionnaire plus the guide questions for the key informant discussion was obtained from the UNISA's College of Agriculture and Environmental Sciences Ethics Committee (Ref no: 2016/CEAS/133) see Appendix 3.

(ii) During the research the nature and research aims were explained verbally to the participants ahead of seeking their consent for their participation in the study. Secondly their rights to participate in the research were explained before they participated in the research.

(iii) Used as a guide to ensure ethical considerations the researcher followed the ethical approval forms from the university.

4.10 Methodological reflections

The research approach employed in this study was a mixed-methods approach involving collecting both quantitative and qualitative data and within this methods approach the study used the explanatory sequential research design. Where the researcher performed quantitative research then analysed the data and results, then built on the results by explaining them in greater detail using qualitative research (Creswell, 2014). The methodology used to collect the quantitative data worked well and the data collected yielded good results. There were however a few gaps identified later during the analysis and discussion of results that could have been averted and these related to specifics such as droughts (the years drought was experienced and associated losses), the onset of the rainy season (date) and more specific data on seasonal climate forecasts and their use by mixed farmers. These gaps could have provided valuable information but became recommendations for future research.

With regard to the qualitative methodologies, these had to be altered, mainly due to the COVID-19 pandemic that restricted gatherings. Initially the study was to use a participatory approach combined with focus group interviews to obtain the farmers' adaptation approaches under different (simulated) climatic conditions. During these discussions it was envisioned that the farmers would be provided with seasonal forecasts plus material to explain these forecasts. In line with this information the farmers would provide information on the adaptation strategies to different climate forecasts. However 'COVID-19' restricted gatherings of persons and alterations were made to substitute the focus group with a key informant to which information on forecasts was shared and adaptation strategies under different climatic scenarios were collected. These alterations made it possible to collect qualitative data which would have been collected with a focus group interview. Such data might not probably fully represent sentiment in the community on a particular issue because the key informants would be more knowledgeable on climate change and adaptation, however given the prevailing circumstances it was deemed the most appropriate, and such an approach was also used by Archer *et al*. (2021) in South Africa. The results obtained also provided insight on adaptation strategies under different climate scenarios.

4.11 Conclusion

This chapter covered the research method, which included the research approach. This study is multidimensional in that it used both quantitative and qualitative data on climate change from scientific models and associated human responses. The mixed research design was thought to be the most appropriate to tackle the various (physical, socio-economic and even political) aspects of the research. Furthermore, the sample selection methods and the way in which data was collected and analysed were also discussed. In this study a multi-stage area sampling approach that ensured proper coverage of farmers within the Lowveld was used.

The types of data required was both primary and secondary in nature. The secondary data was for climate data (historical records) from climatological stations in the Lowveld, climate forecasts, and regional climate projections, and livestock census data. Primary data was obtained from the farmers on their perceptions and adaptations actions, along with data from key informants on policy issues regarding climate change adaptation. The tools for data collection were mainly questionnaires and key informant interview guides. Both quantitative and qualitative techniques were utilised to present and analyse data, namely: descriptive statistics (mainly tables and graphs) and inferential statistics.

In conclusion, the techniques employed as part of the methodology were selected from various studies, 1) to analyse the biographical data of the farmers, 2) to provide an understanding on climate change effects of on livestock farming, 3) to get the farmers climate change perceptions, 4) to find out about the approaches used by farmers currently to adapt to climate change effects, and 5) to identify policy gaps that need to be addressed to assist farmers with climate change, and lastly, to project prospective adaptation options that could be used by farmers following forecasted future climates.

CHAPTER 5

RESEARCH RESULTS.

5.1 Introduction

This chapter presents the data analysis results, and these are arranged and provided in line with the objectives of the study. In this context, the chapter is primarily centred on four research objectives and their associated sub-objectives. The main objectives are: To assess how livestock farming in Eswatini's Lowveld is affected by climate change; To explore the adaptation measures used by livestock farmers for climate change; To establish if knowledge of and availability to access to future climate forecasts and projections will influenced livestock farmers climate change adaptation strategies; To propose policy guidelines that could assist livestock farmers adapt to climate change. Arising out of these objectives are a several sub-objectives and these will be used as a guide to present the results.

The climate trends of the Lowveld of Eswatini are outlined first, followed by a presentation of the socio-demographic variables of the farmers, which are shadowed by the farmers' climate perceptions and adaptation strategies. Then, information on using climate forecasts for adaptation to climate variance is followed by outlining the policy issues that are identified to assist the farmers adapt to climate change.

5.2 Climate trends in the Lowveld of Eswatini

The first objective of this study was to understand how livestock farming in the lowveld of Eswatini was affected by climate change. Before answering this question a sub-objective was to establish if the Lowveld of Eswatini's climate has changed over the past 31 years, and if so, to what extent. To determine the extent of change, it was prudent to examine the climatic trends in the study area. These trends were determined using rainfall and or temperature data from three weather stations in the study area, namely: Big Bend in the south, Mhlume in the north, and Sithobela, which only had rainfall data, is in the central west. The analysis of the data is presented below.

5.2.1 Trend analysis of Mhlume temperatures

For the trend analysis of Mhlume, minimum, maximum and mean temperatures from the meteorological station were used:

5.2.1.1 *Mean monthly temperatures of Mhlume*

Trend analysis of the mean temperatures for Mhlume between 1988 and 2018 revealed that the mean temperatures at this meteorological station ranged from about 27ºC in summer to 16ºC with a few occasions when temperatures drop below 16ºC in winter. There is also a decreasing trend in in temperatures over time (see Figure 5.1).

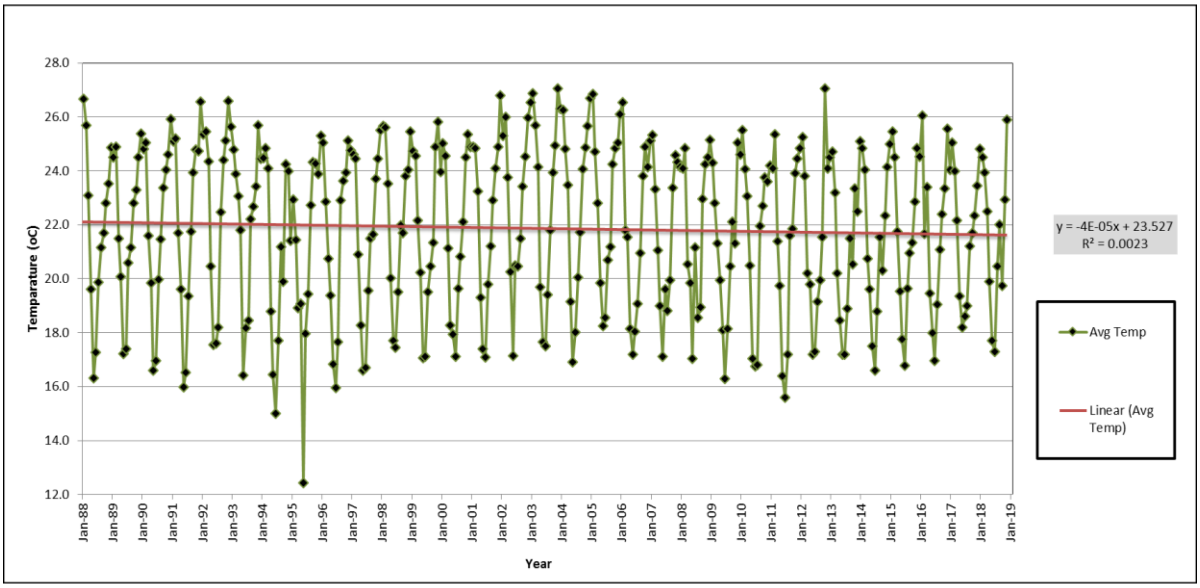


Figure 5-1: Mean temperatures of Mhlume from 1988-2018 including trend lines.
***(Source:** Data from Eswatini Meteorological Service, 2019)*

When the mean temperature was analysed in detail using M-K Test and Sens Slope, the following observations of significance were made. The annual mean temperatures of Mhlume have decreased significantly ($p \leq 0.1$) by 2.125%, by 0.465 ºC over 31 years, or about 0.015 ºC per annum, (see Table 5.1).

At the seasonal level, spring temperatures decreased significantly ($p \leq 0.05$) by 5.626%, by 1.271 ºC over 31 years, or about 0.041 ºC per annum.

Again, at a monthly level the following months were observed to have a significant decrease in temperature.

i. January temperatures decreased significantly ($p < 0.05$) by 4.315%, by 1.07 ºC over 31 years, or about 0.035 ºC per annum.
ii. March temperatures decreased significantly ($p < 0.05$) by 5.624%, by 1.347 ºC over 31 years, or about 0.043 ºC per annum.
iii. October temperatures decreased significantly ($p < 0.05$) by 8.555%, by 1.882 ºC over 31 years, or about 0.061ºC per annum.

However, the mean temperatures in June increased significantly ($p \leq 0.01$) by 7.631% (1.4 ºC) and by 1.351 ºC over 31 years; and that is approximately by 0.044 ºC per annum.

Table 5-1 Trend analysis for Mhlume's Mean annual Temperatures

Mhlume Meteorological Stations Mean Annual Surface Temperature				Mann-Kendall test		Sen's slope	% change in $T_{(Avg)}$ over n yrs	$T_{(Avg)}$ (ºC) change over n yrs.	% change in $T_{(Avg)}$ / year	$T_{(Avg)}$ (ºC) change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	**1988**	**2018**	**31**	**-2.110**	*	**-0.035**	**-4.315**	**-1.070**	**-0.139**	**-0.035**
February	1988	2018	31	0.250		0.006	0.740	0.181	0.024	0.006
March	**1988**	**2018**	**31**	**-2.360**	*	**-0.044**	**-5.624**	**-1.347**	**-0.181**	**-0.043**
April	1988	2018	31	-1.000		-0.028	-3.934	-0.885	-0.127	-0.029
May	1988	2018	31	-0.700		-0.009	-1.413	-0.281	-0.046	-0.009
June	**1988**	**2018**	**31**	**3.100**	**	**0.042**	**7.631**	**1.351**	**0.246**	**0.044**
July	1988	2018	31	0.420		0.007	1.243	0.215	0.040	0.007
August	1988	2018	31	-0.950		-0.025	-4.049	-0.828	-0.131	-0.027
September	1988	2018	31	-1.170		-0.020	-2.906	-0.639	-0.094	-0.021
October	**1988**	**2018**	**31**	**-2.140**	*	**-0.062**	**-8.555**	**-1.882**	**-0.276**	**-0.061**
November	1988	2018	31	-1.090		-0.026	-3.363	-0.771	-0.108	-0.025
December	1988	2018	31	-0.440		-0.008	-1.002	-0.259	-0.032	-0.008
ANNUAL	**1988**	**2018**	**31**	**-1.840**	+	**-0.015**	**-2.125**	**-0.465**	**-0.069**	**-0.015**
III-V (Autumn)	1988	2018	31	-1.460		-0.028	-3.942	-0.868	-0.127	-0.028
VI-VIII(Winter)	1988	2018	31	1.290		0.018	3.120	0.558	0.101	0.018
IX-XI(Spring)	**1988**	**2018**	**31**	**-2.380**	*	**-0.041**	**-5.626**	**-1.271**	**-0.181**	**-0.041**
XII-II(Summer)	1988	2018	31	-1.240		-0.016	-1.983	-0.496	-0.064	-0.016
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.1.2 Maximum monthly temperatures for Mhlume

The trend analysis of the maximum temperatures at Mhlume for the period 1988 to 2018 revealed that the maximum monthly temperatures ranged, on average, between 34ºC in summer and 23ºC in winter, with a few odd extremes below and above. The trend also revealed a declining maximum temperature over time (see Figure 5.2).

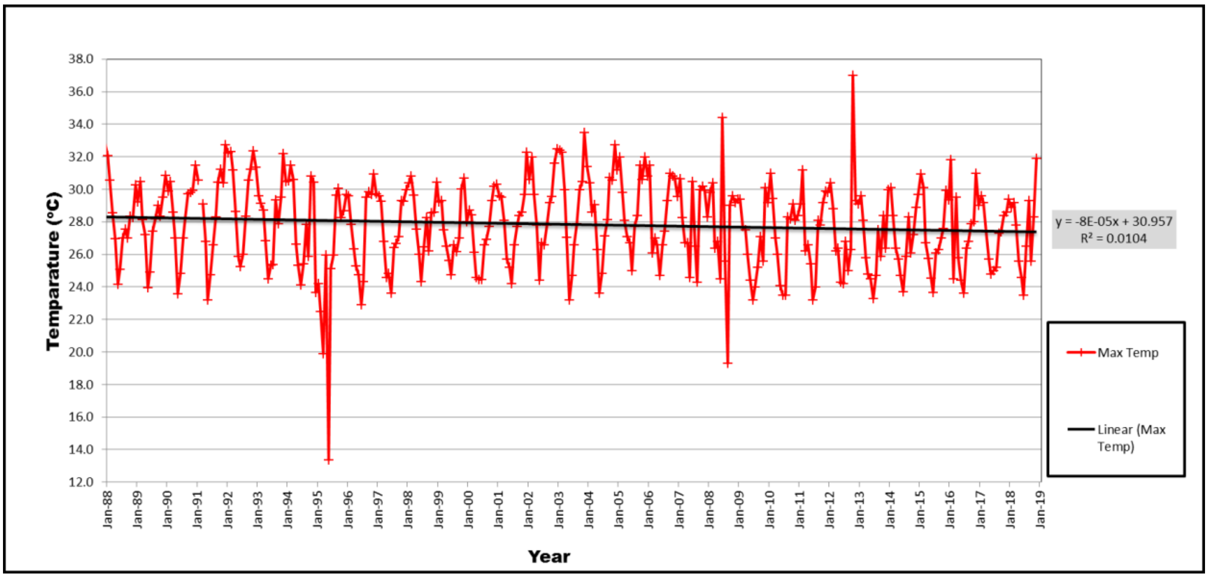


Figure 5-2: Maximum monthly temperatures of Mhlume including trend lines.

*(**Source:** Data from Eswatini Meteorological Service, 2019)*

The maximum monthly temperatures of Mhlume were analysed using M-K Test and Sens Slope to determine if these temperatures had significantly changed over time. The results showed that most months' temperatures changed with time (see Table 5.2); however, reported below are only those with significant changes, where the level of significance is indicated in brackets.

The maximum annual temperatures of Mhlume have decreased significantly ($p \leq 0.05$) by 4.092%; or by 1.139°C over 31 years which translates to about 0.037°C per annum.
For the other remaining seasons of the year, autumn and spring, temperatures decreased significantly. As a matter of fact, autumn temperatures decreased significantly ($p \leq 0.05$) by 6.529%, by 1.813°C over 31 years, or about 0.058°C per annum. Whereas, spring temperatures decreased significantly ($p \leq 0.1$) by 4.726%, by 1.342°C over 31 years, or about 0.043°C per annum.

On a monthly timescale the following months had significant changes in maximum temperatures (see table 5.2):

i. January temperatures decreased significantly ($p < 0.01$) by 6.991%, by 2.055 °C over 31 years, or about 0.066 °C per annum.
ii. March temperatures decreased significantly ($p < 0.1$) by 6.829%, by 1.994 °C over 31 years, or about 0.064 °C per annum.
iii. April temperatures decreased significantly ($p < 0.05$) by 7.81%, °C 2.171 °C over 31 years, or about 0.070 °C per annum.

iv. May temperatures decreased significantly ($p < 0.01$) by 5.516%, by 1.412 °C over 31 years, or about 0.046 °C per annum.

v. October temperatures decreased significantly ($p < 0.1$) by 7.712% by 2.26 °C over 31 years, or about 0.073 °C per annum.

Table 5-2: Trend analysis for maximum temperatures for Mhlume

Mhlume Meteorological Stations Maximum Annual Surface Temperature (°C)				Mann-Kendall test		Sen's slope	% change in $T_{(max)}$ over n yrs	$T_{(max)}$ (°C) change over n yrs.	% change in $T_{(max)}$ / year	$T_{(max)}$ (°C) change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	**1988**	**2018**	**31**	**-2.873**	**	**-0.068**	**-6.991**	**-2.055**	**-0.226**	**-0.066**
February	1988	2018	31	-0.136		0.000	-0.037	-0.011	-0.001	0.000
March	**1988**	**2018**	**31**	**-1.853**	**+**	**-0.065**	**-6.829**	**-1.994**	**-0.220**	**-0.064**
April	**1988**	**2018**	**31**	**-1.990**	*	**-0.070**	**-7.810**	**-2.171**	**-0.252**	**-0.070**
May	**1988**	**2018**	**31**	**-2.875**	**	**-0.047**	**-5.516**	**-1.412**	**-0.178**	**-0.046**
June	1988	2018	31	0.510		0.008	1.019	0.251	0.033	0.008
July	1988	2018	31	-1.633		-0.040	-4.967	-1.167	-0.160	-0.038
August	1988	2018	31	-1.277		-0.019	-2.215	-0.587	-0.071	-0.019
September	1988	2018	31	-1.293		-0.029	-3.298	-0.966	-0.106	-0.031
October	**1988**	**2018**	**31**	**-1.700**	**+**	**-0.070**	**-7.712**	**-2.260**	**-0.249**	**-0.073**
November	1988	2018	31	-1.615		-0.047	-4.970	-1.408	-0.160	-0.045
December	1988	2018	31	-0.629		-0.022	-2.254	-0.719	-0.073	-0.023
ANNUAL	**1988**	**2018**	**31**	**-2.379**	*	**-0.037**	**-4.092**	**-1.139**	**-0.132**	**-0.037**
III-V (Autumn)	**1988**	**2018**	**31**	**-2.244**	*	**-0.058**	**-6.529**	**-1.813**	**-0.211**	**-0.058**
VI-VIII(Winter)	1988	2018	31	-0.833		-0.010	-1.271	-0.319	-0.041	-0.010
IX-XI(Spring)	**1988**	**2018**	**31**	**-1.683**	**+**	**-0.043**	**-4.726**	**-1.342**	**-0.152**	**-0.043**
XII-II(Summer)	1988	2018	31	-1.496		-0.032	-3.290	-0.990	-0.106	-0.032
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.1.3 Minimum Monthly Temperatures for Mhlume

The trend analysis revealed that the minimum temperatures of Mhlume ranged between 23°C in summer and above 5°C in winter. The trend of minimum temperatures, however, revealed a positive trend; meaning, the minimum temperatures were increasing from 1988 to 2018 (see Figure 5.3).

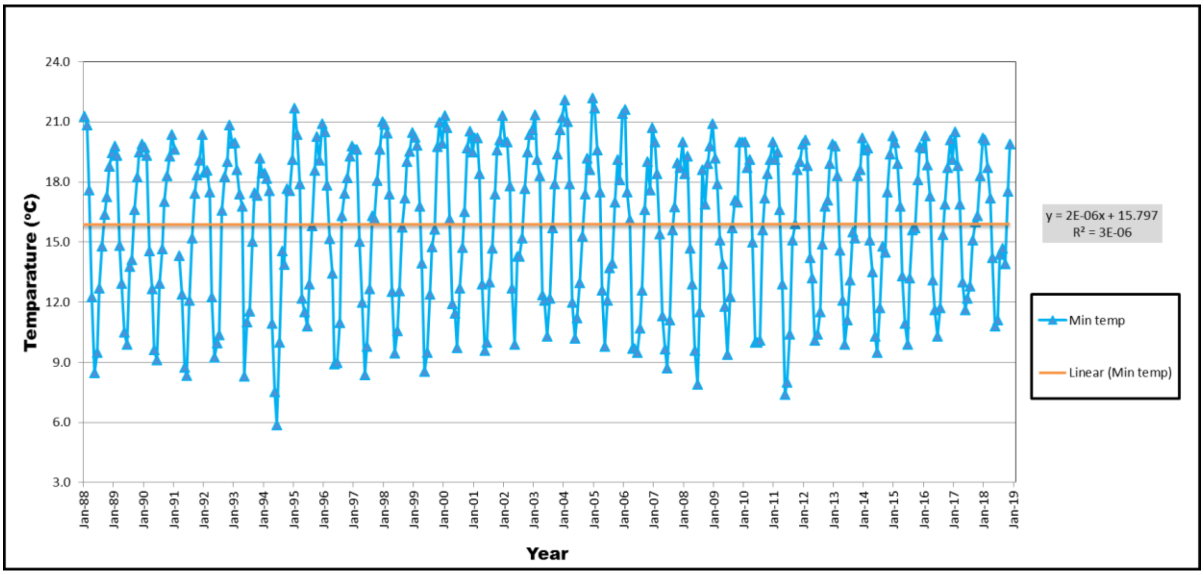


Figure 5-3: Minimum temperatures of Mhlume from 1988-2018 including trend lines.

***(Source:** Data from Eswatini Meteorological Service, 2019)*

On further analysis utilising M-K Test and Sens Slope to determine if Mhlume's minimum monthly temperatures had significantly changed over time, the results revealed that for only two months, June and October, temperatures had significantly changed with time (see Table 5.3). June temperatures had significantly ($p \leq 0.01$) increased by 21.531%, or by 2.325°C over 31 years, or about 0.075 °C per annum. Whereas October temperatures had significantly ($p \leq 0.05$) decreased by 8.902%, or by 1.309°C over 31 years, or about 0.042 °C per annum.

Table 5-3: Trend analysis for minimum temperatures for Mhlume

Mhlume Meteorological Stations Minimum Annual Surface Temperature				Mann-Kendall test		Sen's slope	% change in $T_{(Min)}$ over n yrs	$T_{(Min)}$ (°C) change over n yrs.	% change in $T_{(Min)}$ / year	$T_{(Min)}$ (°C) change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	-0.051		0.000	0.000	0.000	0.000	0.000
February	1988	2018	31	0.187		0.002	0.258	0.052	0.008	0.002
March	1988	2018	31	-1.394		-0.030	-4.857	-0.908	-0.157	-0.029
April	1988	2018	31	-0.272		-0.006	-1.060	-0.182	-0.034	-0.006
May	1988	2018	31	1.616		0.029	6.748	0.958	0.218	0.031
June	**1988**	**2018**	**31**	**2.942**	**	**0.068**	**21.531**	**2.325**	**0.695**	**0.075**
July	1988	2018	31	1.531		0.032	10.036	1.114	0.324	0.036
August	1988	2018	31	0.272		0.006	1.588	0.229	0.051	0.007
September	1988	2018	31	-0.017		0.000	0.000	0.000	0.000	0.000
October	**1988**	**2018**	**31**	**-2.262**	*	**-0.048**	**-8.902**	**-1.309**	**-0.287**	**-0.042**
November	1988	2018	31	-1.428		-0.036	-6.106	-1.071	-0.197	-0.035
December	1988	2018	31	-0.102		-0.004	-0.640	-0.127	-0.021	-0.004
ANNUAL	1988	2018	31	-0.272		-0.004	-0.761	-0.121	-0.025	-0.004
III-V (Autumn)	1988	2018	31	-0.170		-0.003	-0.629	-0.102	-0.020	-0.003
VI-VIII(Winter)	1988	2018	31	1.564		0.035	10.026	1.070	0.323	0.035
IX-XI(Spring)	1988	2018	31	-1.632		-0.022	-4.130	-0.693	-0.133	-0.022
XII-II(Summer)	1988	2018	31	-0.034		0.000	-0.050	-0.010	-0.002	0.000
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.2 Trend analysis of Big Bend temperatures

5.2.2.1 Mean monthly temperatures of Big Bend

The trend plot of the Big Bend mean temperatures from 1988 to 2018, revealed that on average the mean monthly temperatures range between 27.5°C in summer to about 16°C with a few occasions when temperatures drop below 16°C in winter. The trend plot indicates an increasing trend in temperatures over time with an estimated increase of about 0.75 °C (see Figure 5.4).

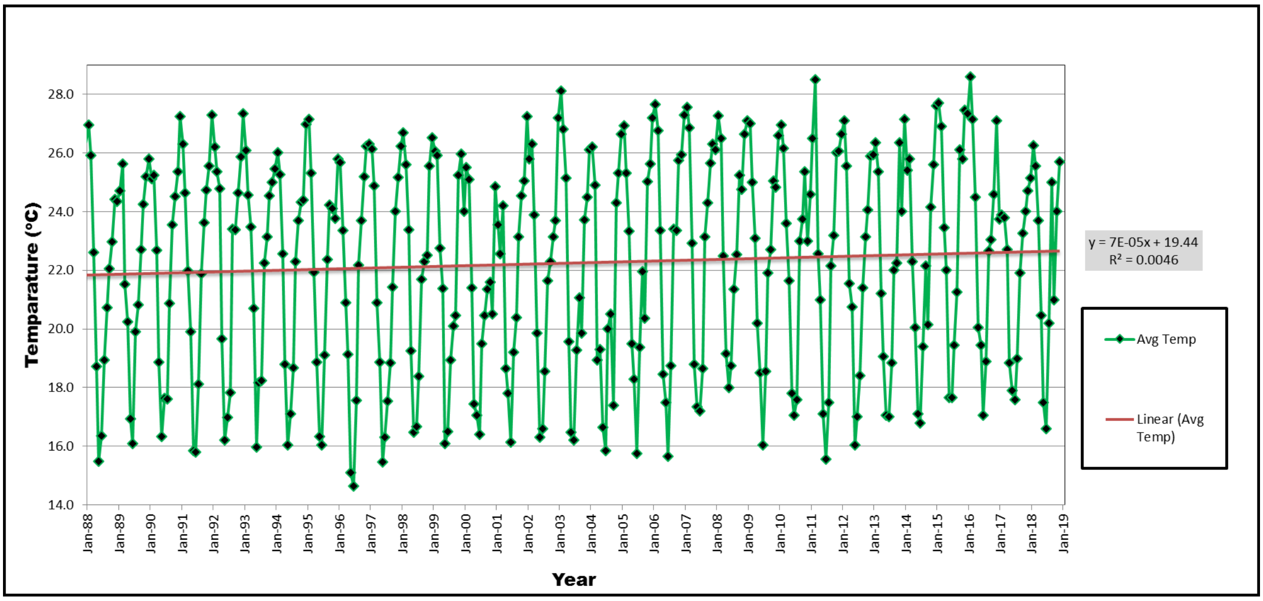


Figure 5-4: Mean monthly temperatures of Big Bend including trend lines.
(Source: Data from Eswatini Meteorological Service, 2019)

A further exploration utilising the M-K Test and Sen's Slope was done to determine if the mean monthly temperatures of Big Bend had significantly changed over time. The results, (as shown on Table 5.4), revealed that:

i. The mean annual monthly temperatures of Big Bend had increased significantly ($p \leq 0.01$) by 3.92%, by 0.872 over 31 years, or about 0.028 per annum.

ii. At a seasonal level, the mean winter monthly temperatures increased significantly ($p \leq 0.001$) by 6.488%, by 1.132°C over 31 years, or about 0.037°C per annum.

iii. On a monthly timescale the temperatures of the following months had significant changes in mean temperatures:

a. February temperatures increased significantly ($p \leq 0.1$) by 3.919%, by 1.029 °C over 31 years, or about 0.033 °C per annum.
b. March temperatures increased significantly ($p \leq 0.1$) by 4.809%, by 1.229 °C over 31 years, or about 0.040 °C per annum.
c. June temperatures increased significantly ($p \leq 0.001$) by 13.025%, by 2.279 °C over 31 years, or about 0.074 °C per annum.
d. August temperatures increased significantly ($p \leq 0.1$) 4.953%, by 1.001 °C over 31 years, or about 0.032 °C per annum.

e. September temperatures increased significantly ($p \leq 0.1$) by 6.167%, by 1.542 ^{o}C over 31 years, or about 0.050 ^{o}C per annum.

Table 5-4: Trend analysis for mean temperatures for Big Bend

Big Bend Meteorological Stations Mean Annual Surface Temperature				Mann-Kendall test		Sen's slope	% change in T(Avg) over n yrs	T(Avg) (oC) change over n yrs.	% change in T(Avg) / year	T(Avg) (oC) change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	0.340		0.007	0.843	0.212	0.027	0.007
February	1988	2018	31	1.666	+	0.033	3.919	1.029	0.126	0.033
March	1988	2018	31	1.887	+	0.040	4.809	1.229	0.155	0.040
April	1988	2018	31	0.748		0.020	2.731	0.647	0.088	0.021
May	1988	2018	31	1.564		0.035	5.573	1.140	0.180	0.037
June	1988	2018	31	3.945	***	0.071	13.025	2.279	0.420	0.074
July	1988	2018	31	0.935		0.020	3.660	0.608	0.118	0.020
August	1988	2018	31	1.683	+	0.030	4.953	1.001	0.160	0.032
September	1988	2018	31	1.700	+	0.043	6.167	1.542	0.199	0.050
October	1988	2018	31	-0.289		-0.010	-1.311	-0.328	-0.042	-0.011
November	1988	2018	31	1.394		0.032	4.054	0.973	0.131	0.031
December	1988	2018	31	1.564		0.029	3.592	0.923	0.116	0.030
ANNUAL	1988	2018	31	2.583	**	0.028	3.920	0.872	0.126	0.028
III-V (Autumn)	1988	2018	31	1.581		0.030	4.050	0.917	0.131	0.030
VI-VIII(Winter)	1988	2018	31	3.467	***	0.037	6.488	1.132	0.209	0.037
IX-XI(Spring)	1988	2018	31	1.258		0.028	3.751	0.861	0.121	0.028
XII-II(Summer)	1988	2018	31	1.156		0.021	2.563	0.665	0.083	0.021
Significance : *** for p < 0.001, ** for p < 0.01, * for p < 0.05, + for p < 0.1										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.2.2 Maximum Monthly Temperatures for Big Bend

The trend plot of the maximum monthly temperatures for Big Bend from 1988 to 2018 revealed that, on average, the maximum monthly temperatures ranged between 34^{o}C in summer to about 24.5^{o}C with a few occasions when temperatures dropped below 24^{o}C in winter. The trend plot indicates an increasing trend in the Maximum temperatures over time with an estimated increase of about 0.9 ^{o}C (see Figure 5.5).

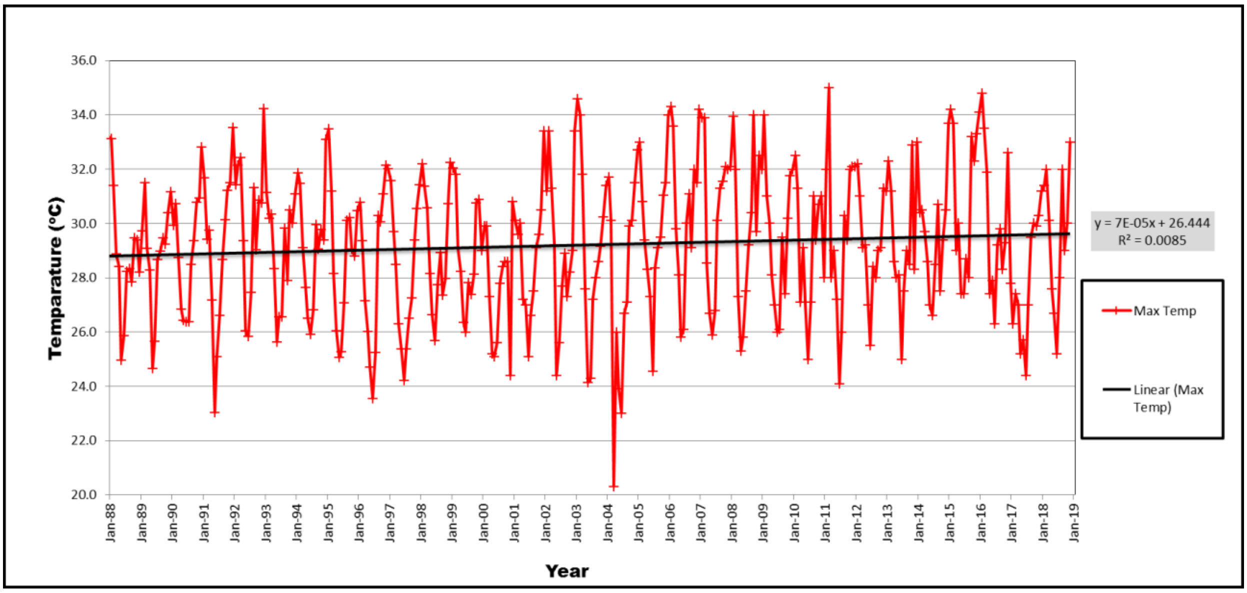


Figure 5-5: Maximum temperatures of Big Bend from 1988-2018 including trend lines.

***(Source:** Data from Eswatini Meteorological Service, 2019)*

On further probing by way of M-K Test and Sen's Slope to determine if the maximum monthly temperatures had significantly changed over the years, the outcome (see table 5.5) revealed that:

(i) At an annual scale the maximum annual monthly temperatures of Big Bend had increased significantly ($p \leq 0.05$) by 2.982 %, by 0.871 over 31 years, or about 0.028 °C per annum

.

(ii) On a seasonal level the maximum winter monthly temperatures increased significantly ($p \leq 0.05$) by 4.413%, by 1.163°C over 31 years, or about 0.038°C per annum.

(iii) On a monthly timescale the following months temperatures had significant changes in maximum temperatures:

a. February temperatures increased significantly ($p \leq 0.1$) by 4.845%, by 1.521 °C over 31 years, or about 0.049 °C per annum.
b. June temperatures increased significantly ($p \leq 0.01$) by 8.599%, by 2.296 °C over 31 years, or about 0.074 °C per annum.
c. August temperatures increased significantly ($p \leq 0.1$) by 5.371%, by 1.504°C over 31 years, or about 0.049 °C per annum.
d. December temperatures increased significantly ($p \leq 0.05$) by 7.408%, by 2.445°C over 31 years, or about 0.079 °C per annum.

Table 5-5: Trend analysis for maximum temperatures for Big Bend

Big Bend Meteorological Station's Maximum Annual Surface Temperature (^oC)				Mann-Kendall test		Sen's slope	% change in $T_{(max)}$ over n yrs	$T_{(max)}$ (^oC) change over n yrs.	% change in $T_{(max)}$ / year	$T_{(max)}$ (^oC) change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	0.000		0.000	0.000	0.000	0.000	0.000
February	**1988**	**2018**	**31**	**1.768**	**+**	**0.050**	**4.845**	**1.521**	**0.156**	**0.049**
March	1988	2018	31	1.190		0.050	4.932	1.578	0.159	0.051
April	1988	2018	31	-0.272		-0.006	-0.668	-0.201	-0.022	-0.006
May	1988	2018	31	0.204		0.012	1.309	0.361	0.042	0.012
June	**1988**	**2018**	**31**	**3.183**	******	**0.072**	**8.599**	**2.296**	**0.277**	**0.074**
July	1988	2018	31	-0.068		-0.003	-0.392	-0.099	-0.013	-0.003
August	**1988**	**2018**	**31**	**1.819**	**+**	**0.048**	**5.371**	**1.504**	**0.173**	**0.049**
September	1988	2018	31	1.361		0.042	4.450	1.424	0.144	0.046
October	1988	2018	31	0.408		0.009	0.929	0.297	0.030	0.010
November	1988	2018	31	0.833		0.024	2.415	0.724	0.078	0.023
December	**1988**	**2018**	**31**	**2.400**	*****	**0.073**	**7.408**	**2.445**	**0.239**	**0.079**
ANNUAL	**1988**	**2018**	**31**	**2.379**	*****	**0.028**	**2.982**	**0.871**	**0.096**	**0.028**
III-V (Autumn)	1988	2018	31	0.986		0.017	1.761	0.517	0.057	0.017
VI-VIII(Winter)	**1988**	**2018**	**31**	**2.278**	*****	**0.038**	**4.413**	**1.163**	**0.142**	**0.038**
IX-XI(Spring)	1988	2018	31	1.581		0.036	3.763	1.113	0.121	0.036
XII-II(Summer)	1988	2018	31	1.224		0.035	3.392	1.070	0.109	0.035
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.2.3 Minimum Monthly Temperatures for Big Bend

The trend plot for the minimum monthly temperatures for Big Bend from 1988 to 2018 revealed that, on average, the minimum monthly temperatures ranged between 21^{o}C in summer to about 6^{o}C, with a few occasions when temperatures drop below 6^{o}C in winter. The trend plot indicates an increasing trend in the minimum temperatures over time with an estimated increase of about 0.8 ^{o}C (see Figure 5.6).

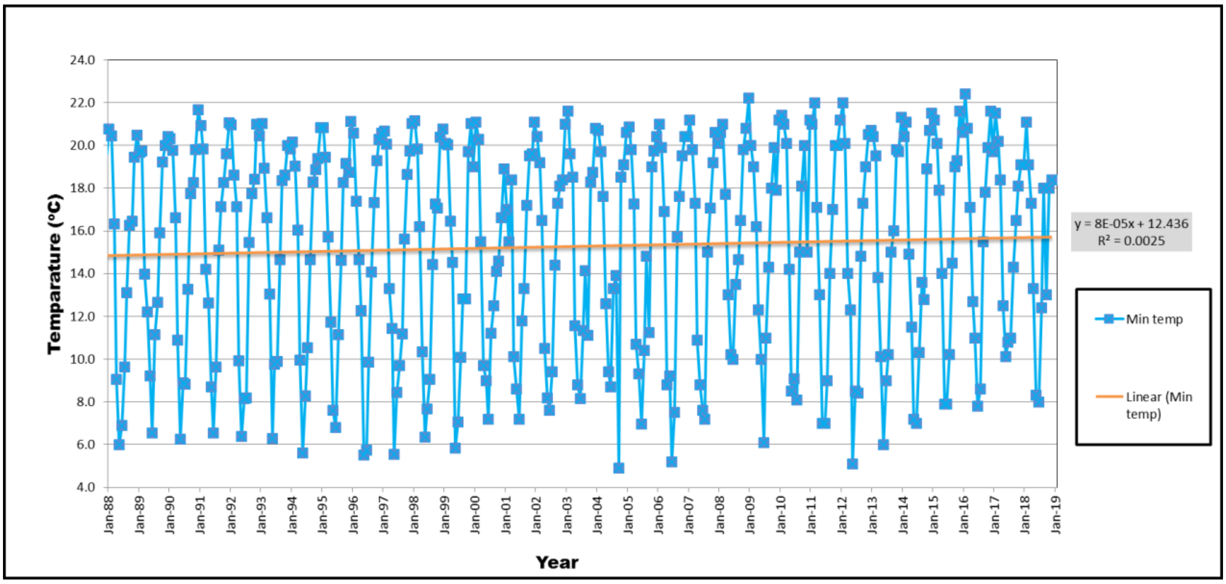


Figure 5-6: Minimum temperatures of Big Bend from 1988-2018 including trend lines.
***(Source:** Data from Eswatini Meteorological Service, 2019)*

On further analysis utilising Mann-Kendall (M-K) test and Sens slope to determine if Big Bend's minimum monthly temperatures had significantly changed over time, the outcome (see Table 5.6) revealed that:

(i) On an annual scale the minimum annual monthly temperatures of Big Bend had increased significantly ($p \leq 0.01$) by 5.76 %, by 0.881 over 31 years, or about 0.028 per annum.

(ii) At a seasonal level the results (see Table 5.6) revealed that:

a. The minimum autumn monthly temperatures increased significantly ($p \leq 0.05$) by 9.262%, by 1.476°C over 31 years, or about 0.048°C per annum.

b. The minimum winter monthly temperatures increased significantly ($p \leq 0.1$) by 12.277%, by 1.049°C over 31 years, or about 0.034°C per annum.

(iii) On a monthly timescale seven months temperatures had significant changes in their minimum monthly temperatures: These months are:

a. February temperatures increased significantly ($p \leq 0.05$) by 4.118%, by 0.869 °C over 31 years, or about 0.028 °C per annum.

b. March temperatures increased significantly ($p \leq 0.05$) by 5.245%, by 1.002 °C over 31 years, or about 0.032 °C per annum.

c. April temperatures increased significantly ($p \leq 0.05$) by 10.528% , by 1.821 °C over 31 years, or about 0.059 °C per annum.

d. May temperatures increased significantly ($p \leq 0.05$) by 17.769%, by 2.363 °C over 31 years, or about 0.076 °C per annum.

e. June temperatures increased significantly ($p \leq 0.1$) by 31.851%, by 2.644 °C over 31 years, or about 0.085 °C per annum.

f. September temperatures increased significantly ($p \leq 0.1$) by 9.03%, by 1.625ºC over 31 years, or about 0.052 ºC per annum.

g. November temperatures increased significantly ($p \leq 0.05$) by 7.084%, by 1.275ºC over 31 years, or about 0.041 ºC per annum.

Table 5-6: Trend analysis for Big Bend's minimum temperatures

Big Bend Meteorological Stations Minimum Annual Surface Temperature				Mann-Kendall test		Sen's slope	% change in $T_{(Min)}$ over n yrs	$T_{(Min)}$ (ºC) change over n yrs.	% change in $T_{(Min)}$ / year	$T_{(Min)}$ (ºC) change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	0.663		0.009	1.355	0.259	0.044	0.008
February	**1988**	**2018**	**31**	**2.314**	*	**0.028**	**4.118**	**0.869**	**0.133**	**0.028**
March	**1988**	**2018**	**31**	**2.108**	*	**0.033**	**5.245**	**1.002**	**0.169**	**0.032**
April	**1988**	**2018**	**31**	**2.040**	*	**0.056**	**10.528**	**1.821**	**0.340**	**0.059**
May	**1988**	**2018**	**31**	**2.091**	*	**0.067**	**17.769**	**2.363**	**0.573**	**0.076**
June	**1988**	**2018**	**31**	**1.921**	**+**	**0.080**	**31.851**	**2.644**	**1.027**	**0.085**
July	1988	2018	31	1.309		0.038	14.982	1.199	0.483	0.039
August	1988	2018	31	0.578		0.019	5.951	0.738	0.192	0.024
September	**1988**	**2018**	**31**	**1.888**	**+**	**0.042**	**9.030**	**1.625**	**0.291**	**0.052**
October	1988	2018	31	-0.748		-0.022	-4.257	-0.766	-0.137	-0.025
November	**1988**	**2018**	**31**	**2.279**	*	**0.043**	**7.084**	**1.275**	**0.229**	**0.041**
December	1988	2018	31	0.544		0.014	2.258	0.416	0.073	0.013
ANNUAL	**1988**	**2018**	**31**	**2.617**	**	**0.028**	**5.760**	**0.881**	**0.186**	**0.028**
III-V (Autumn)	**1988**	**2018**	**31**	**2.499**	*	**0.048**	**9.262**	**1.476**	**0.299**	**0.048**
VI-VIII(Winter)	**1988**	**2018**	**31**	**1.904**	**+**	**0.034**	**12.277**	**1.049**	**0.396**	**0.034**
IX-XI(Spring)	1988	2018	31	1.037		0.021	3.980	0.651	0.128	0.021
XII-II(Summer)	1988	2018	31	1.224		0.016	2.365	0.481	0.076	0.016
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.3 Trend analysis of rainfall at Mhlume

The graphical presentation of the annual total rainfall for Mhlume was plotted to determine temporal trends as outlined in Figure 5.7 below. The plot indicates a downward trend in total annual rainfall from about 650mm per annum to 450mm per annum.

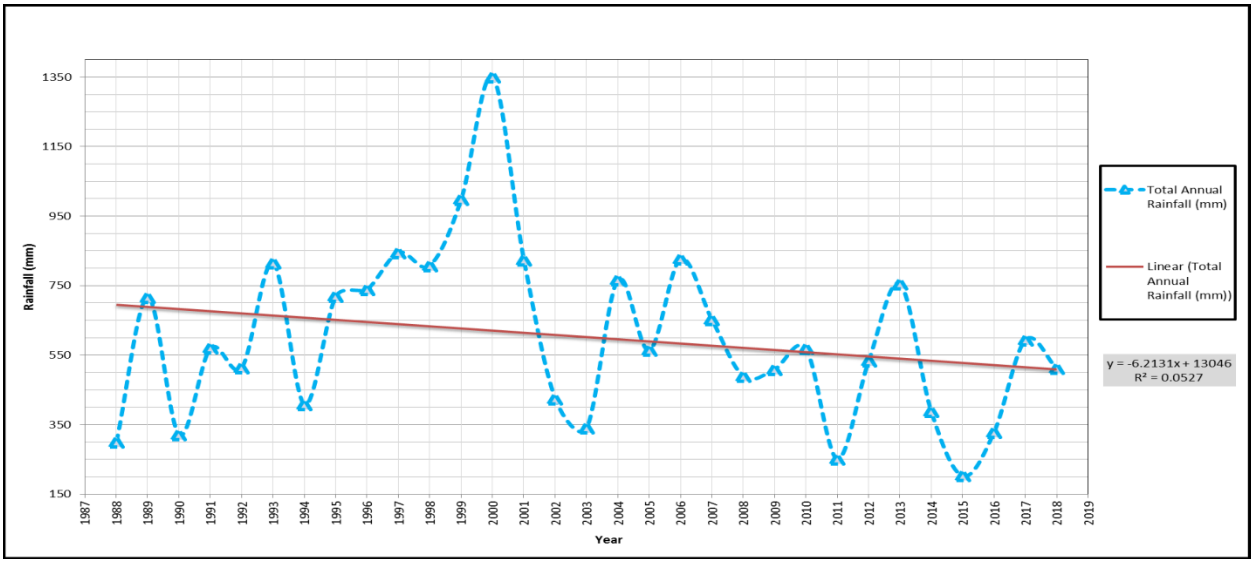


Figure 5-7: Total Annual rainfall of Mhlume with associated trend line

***(Source:** Data from Eswatini Meteorological Service, 2019)*

Additional assessment of Mhlume's rainfall data was done utilising M-K Test and Sen's Slope to determine if Mhlume's monthly rainfall had significantly changed over time. The results (see Table 5.7) revealed the following:

(i) On a monthly time scale the following month's rainfall had significantly changed.

   a. February's rainfall decreased significantly ($p \leq 0.05$) by 71.056%, by 64.325mm over 31 years, or about 2.292mm per year.

   b. December's rainfall decreased significantly ($p \leq 0.05$) by 61.867%, by 67.203mm over 31 years, or about 1.996mm per year.

(ii) While on a seasonal time scale, the summer month's rainfall decreased significantly ($p \leq 0.05$) by 174.68 %, by 186.93mm over 31 years, or about 5.635mm per year.

Table 5-7: Trend analysis for rainfall for Mhlume

Mhlume Meteorological Stations Rainfall Statistical Analysis				Mann-Kendall test		Sen's slope	% change over n yrs.	mm change over n yrs.	% change / year	mm change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	-0.527		-0.833	-21.195	-25.833	-0.684	-0.833
February	**1988**	**2018**	**31**	**-2.159**	*	**-2.075**	**-71.056**	**-64.325**	**-2.292**	**-2.075**
March	1988	2018	31	-1.032		-0.986	-41.066	-30.563	-1.325	-0.986
April	1988	2018	31	-0.375		-0.224	-15.338	-6.948	-0.495	-0.224
May	1988	2018	31	-0.089		0.000	0.000	0.000	0.000	0.000
June	1988	2018	31	-1.644		-0.244	-55.824	-7.554	-1.801	-0.244
July	1988	2018	31	1.111		0.113	47.320	3.488	1.526	0.113
August	1988	2018	31	-0.376		-0.033	-10.620	-1.033	-0.343	-0.033
September	1988	2018	31	0.732		0.155	21.607	4.805	0.697	0.155
October	1988	2018	31	0.094		0.063	2.165	0.481	0.070	0.016
November	1988	2018	31	-0.206		-0.317	-10.870	-9.832	-0.351	-0.317
December	**1988**	**2018**	**31**	**-2.336**	*	**-2.168**	**-61.879**	**-67.221**	**-1.996**	**-2.168**
ANNUAL	1988	2018	31	-1.462		-7.033	-31.556	-218.03	-1.018	-7.033
III-V (Autumn)	1988	2018	31	-0.374		-0.641	-14.593	-19.863	-0.471	-0.641
VI-VIII(Winter)	1988	2018	31	-0.884		-0.413	-41.745	-12.788	-1.347	-0.413
IX-XI(Spring)	1988	2018	31	0.187		0.363	5.544	11.263	0.179	0.363
XII-II(Summer)	**1988**	**2018**	**31**	**-2.379**	*	**-6.030**	**-174.68**	**-186.93**	**-5.635**	**-6.030**
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.4 Trend analysis of rainfall at Big Bend

The detailed presentation of the annual total rainfall for Big Bend was plotted to determine temporal trends as outlined in Figure 5.8 below. The plot indicates an increasing trend in total annual rainfall from about 510mm per annum to 555mm per annum over the 31 year period.

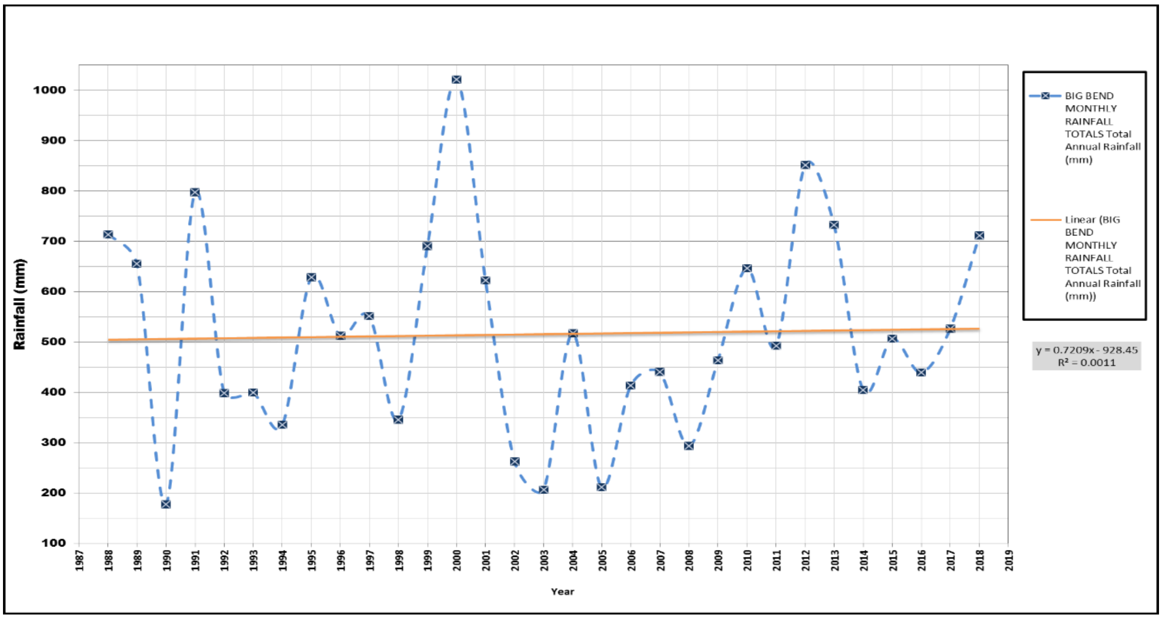


Figure 5-8: Total Annual rainfall of Big Bend with associated trend line

***(Source:** Data from Eswatini Meteorological Service, 2019)*

Further assessment of rainfall data for Big Bend was done employing M-K Test and Sen's Slope to determine if the monthly rainfall had significantly changed over time.

The results of the analysis as indicated in Table 5.8 disclose that:

(i) There was no significant change in rainfall in Big Bend over 31 years, on a year to year basis and on a seasonal basis.

(ii) On a monthly basis, the June rainfall had significantly ($p \leq 0.1$) decreased by 29.845%, by 3.348mm over 31 years, or about 0.108mm per year.

Table 5-8 Trend analysis for rainfall for Big Bend

Big Bend Meteorological Stations Rainfall Statistical Analysis				Mann-Kendall test		Sen's slope	% change over n yrs	mm change over n yrs.	% change / year	mm change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	1.02		1.01	38.96	31.44	1.26	1.01
February	1988	2018	31	-0.78		-0.66	-29.56	-20.39	-0.95	-0.66
March	1988	2018	31	0.50		0.52	24.35	16.02	0.79	0.52
April	1988	2018	31	-0.09		-0.07	-7.30	-2.25	-0.24	-0.07
May	1988	2018	31	1.05		0.21	32.63	6.51	1.05	0.21
June	**1988**	**2018**	**31**	-1.96	+	-0.11	**-29.82**	**-3.35**	**-0.96**	**-0.11**
July	1988	2018	31	-0.63		0.00	0.00	0.00	0.00	0.00
August	1988	2018	31	0.37		0.00	0.00	0.00	0.00	0.00
September	1988	2018	31	1.53		0.35	56.08	10.78	1.81	0.35
October	1988	2018	31	-0.32		-0.18	-9.52	-1.83	-0.31	-0.06
November	1988	2018	31	0.71		0.99	40.19	22.91	1.30	0.74
December	1988	2018	31	-0.77		-1.07	-32.94	-25.24	-1.06	-0.81
ANNUAL	1988	2018	31	0.44		1.45	8.18	44.99	0.26	1.45
III-V (Autumn)	1988	2018	31	1.16		1.86	49.39	57.61	1.59	1.86
VI-VIII(Winter)	1988	2018	31	-0.34		-0.17	-17.22	-5.17	-0.56	-0.17
IX-XI(Spring)	1988	2018	31	1.19		2.00	40.56	62.00	1.31	2.00
XII-II(Summer)	1988	2018	31	-0.42		-0.98	-36.50	-30.51	-1.18	-0.98
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

(Source: *Data from Eswatini Meteorological Service, 2019)*

5.2.5 Trend analysis of rainfall at Sithobela

The graphical presentation of the annual total rainfall for Sithobela was plotted to determine temporal trends as outlined in Figure 5.9 below. The plot indicates an increasing trend in total annual rainfall from about 540 mm per annum to 570mm per annum over the 31 year period. The increase of about 5 % is not significant, though (see Table 5.9).

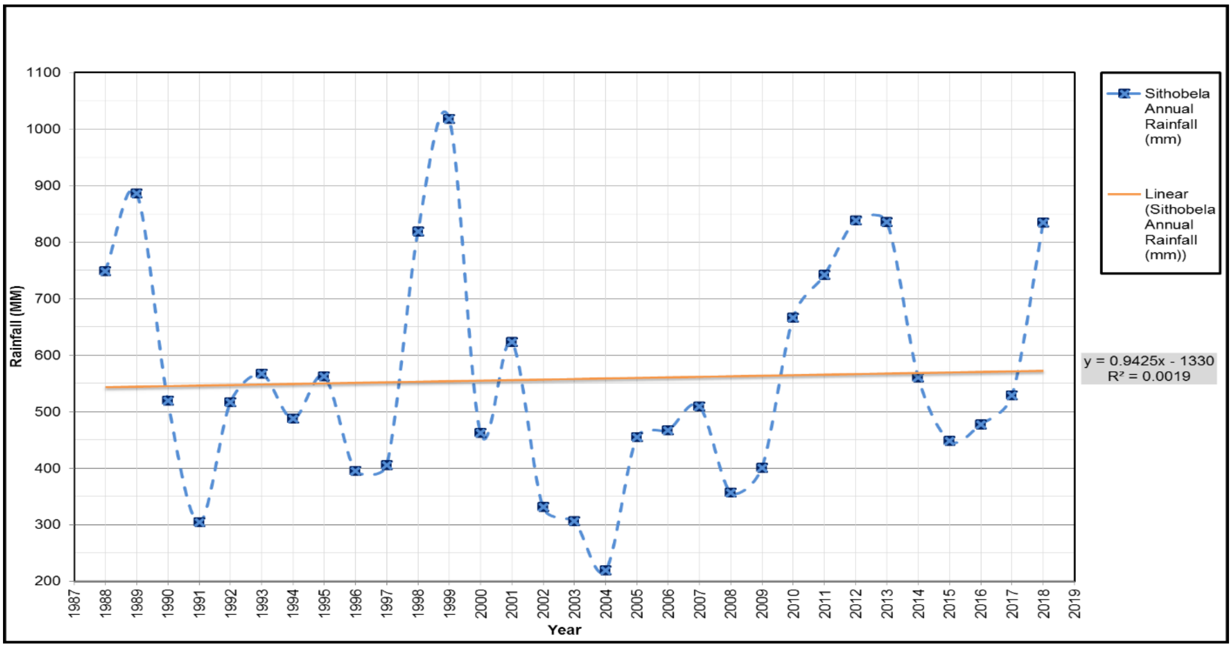


Figure 5-9: Total Annual rainfall of Sithobela with associated trend line
(Source: Data from Eswatini Meteorological Service, 2019)

An added assessment of Sithobela's rainfall data was done by means of M-K Test and Sen's Slope to determine if the monthly rainfall had significantly changed over time. The results (see Table 5.11) disclosed the following:

(i) On a year to year and seasonal time scale basis there was no significant change in Sithobela's rainfall over 31 years.

(ii) On a monthly time-scale the following month's rainfall had significantly changed.

(iii) June rainfall decreased significantly ($p \leq 0.01$) by 73.564%, by 17.285mm over 31 years, or about (0.558mm) per annum.

(iv) October rainfall decreased significantly ($p \leq 0.1$) by 105.29%, by 31.801mm over 31 years, or about 1.026mm per annum.

Table 5-9: Trend analysis for rainfall for Sithobela

Sithobela Meteorological Station Rainfall Statistical Analysis				Mann-Kendall test		Sen's slope	% change over n yrs	mm change over n yrs.	% change / year	mm change / year
Time series	First year	Last Year	n	Test Z	Sig.	Q				
January	1988	2018	31	0.26		0.284	9.189	8.802	0.296	0.284
February	1988	2018	31	-0.49		-0.550	-22.015	-17.050	-0.710	-0.550
March	1988	2018	31	0.23		0.305	11.542	9.448	0.372	0.305
April	1988	2018	31	-1.34		-0.944	-75.150	-29.278	-2.424	-0.944
May	1988	2018	31	0.45		0.000	0.000	0.000	0.000	0.000
June	**1988**	**2018**	**31**	**-2.69**	**	**-0.558**	**-73.564**	**-17.285**	**-2.373**	**-0.558**
July	1988	2018	31	-0.30		0.000	0.000	0.000	0.000	0.000
August	1988	2018	31	-0.43		0.000	0.000	0.000	0.000	0.000
September	1988	2018	31	-0.02		0.000	0.000	0.000	0.000	0.000
October	**1988**	**2018**	**31**	**-1.90**	**+**	**-2.438**	**-105.29**	**-31.801**	**-3.396**	**-1.026**
November	1988	2018	31	0.86		1.258	54.354	39.008	1.753	1.258
December	1988	2018	31	0.21		0.406	15.155	12.594	0.489	0.406
ANNUAL	1988	2018	31	0.24		1.030	5.106	31.930	0.165	1.030
III-V (Autumn)	1988	2018	31	1.51		2.341	50.228	72.568	1.620	2.341
VI-VIII(Winter)	1988	2018	31	-1.01		-0.328	-20.011	-10.168	-0.646	-0.328
IX-XI(Spring)	1988	2018	31	0.00		0.000	0.000	0.000	0.000	0.000
XII-II(Summer)	1988	2018	31	-0.07		-0.100	-3.628	-3.100	-0.117	-0.100
Significance : *** for $p \leq 0.001$, ** for $p \leq 0.01$, * for $p \leq 0.05$, + for $p \leq 0.1$										

***(Source:** Data from Eswatini Meteorological Service, 2019)*

5.2.6 Summary climate trends for the Lowveld of Eswatini

The results indicate that the climate of the Lowveld of Eswatini has significantly changed over the last 31 years (1988-2018). Two indicators were used in the evaluation of temperature and rainfall. To evaluate temperature, the mean, minimum and maximum temperatures were utilised using Mhlume, in the north, and Big Bend, in the south as proxies.

The mean annual temperatures from Mhlume declined by 0.46ºC over the 31 year. The spring temperatures decreased by 1.3 ºC. Similarly, for the months of January, March, and October temperatures decreased by over 1.1 ºC. Only the June temperature increased by 1.4 ºC. For the maximum temperatures there was a significant decline in annual temperature by 1.1 ºC, and in autumn and spring by over 1.3 ºC. In the months of January, March, April, May and October the decline was between 1.4 ºC and 2.2ºC. With the minimum temperatures, the only significant change was for June temperatures that increased by 2.3ºC and October temperatures decreased by 1.3ºC.

At Big Bend the mean annual temperatures increased significantly by 0.9 ºC over 31 years. Similarly, winter temperatures increased by 1.1ºC; and during the months of February, March, June, August, and September temperatures also significantly increased by over 1 ºC. The maximum annual temperatures for Big Bend increased by 0.9 ºC; correspondingly, winter maximum temperatures increased by 1.2ºC as well as in the months of February, June, August, and December where temperatures increased by over 1.5 ºC, while the minimum annual temperature increased significantly by 0.9 ºC, with a seasonal increase for autumn (1.5ºC) and winter (11ºC) temperatures. Likewise, for the months of February (0.9 ºC), March (1.0 ºC), April (1.8 ºC), May (2.4 ºC), June (2.6ºC), September (1.6ºC), and November (1.3ºC) temperatures increased significantly.

With regards to rainfall patterns, three rainfall measuring stations were used, and the results also indicated some changes in Mhlume, Big Bend and Sithobela.

For Mhlume, in the North, the summer season's rainfall decreased significantly by 187mm over 31 years; likewise, for the month of February rainfall decreased by 71% (64mm), and the December rainfall decreased by 62% (67 mm). For Big Bend, in the South, there was no significant change in the amount of rainfall on a year to year basis, and on a seasonal basis, but only for the month of June a decrease of by 30 percent (3.3mm) was noted. For Sithobela, in the central Lowveld, on a year to year and seasonal time-scale basis, there was no significant change except for a decrease in rainfall in June (74 % / 17mm) and October (105 % / 32mm).

5.3 Biographical data of respondents

Before addressing the primary results with regard to the different research questions and objectives, it was paramount to present biographical (the descriptive data) of the sampled population as obtained from the questionnaires. This is done to provide the contextual setting and socio-economic background of the study. These results are presented using a mix of various descriptive techniques, such as verbal descriptions, tables, figures, statistical and associated graphical illustrations for each variable under analysis. The biographical information and associated socio-economic data collected for the population includes: gender, age, marital status, educational level, employment status, occupation and household size.

5.3.1 *The respondents gender composition*

With respect to gender, the majority (78%) of the participants were males, whilst 22% were females. From the study, it was evident that livestock farming in Eswatini tends to be male dominated (see Table 5.10).

Table 5-10: Cross tabulation of gender against age

		Age Range (%)						Total (%)
		18-20 years	20-29 years	30-39 years	40-49 years	50-59 years	≥60 years	
Gender	Male	1	8	8	8	22	31	**78**
	Female	0	1	4	4	8	6	**22**
	Total	**1**	**9**	**12**	**12**	**29**	**37**	**100**

5.3.2 *The respondents age composition*

The age composition of the respondents ranged from 18 – 60 plus years. It was noted that the majority (66%) of the respondents were above 50 years, whereby 37% were 60 years and above. 29 % of the respondent's age ranged from 50-59 years. The lower age group ranged from 12% for 40 to 49 years to 1% for the ages 18-20 years (see Figure 5.10 and Table 5.13). From the results, it was apparent that most of the farmers are old, and there are few young farmers. This is mainly due to the fact that most households own cattle that are, in most cases, under the control of the head of the homestead.

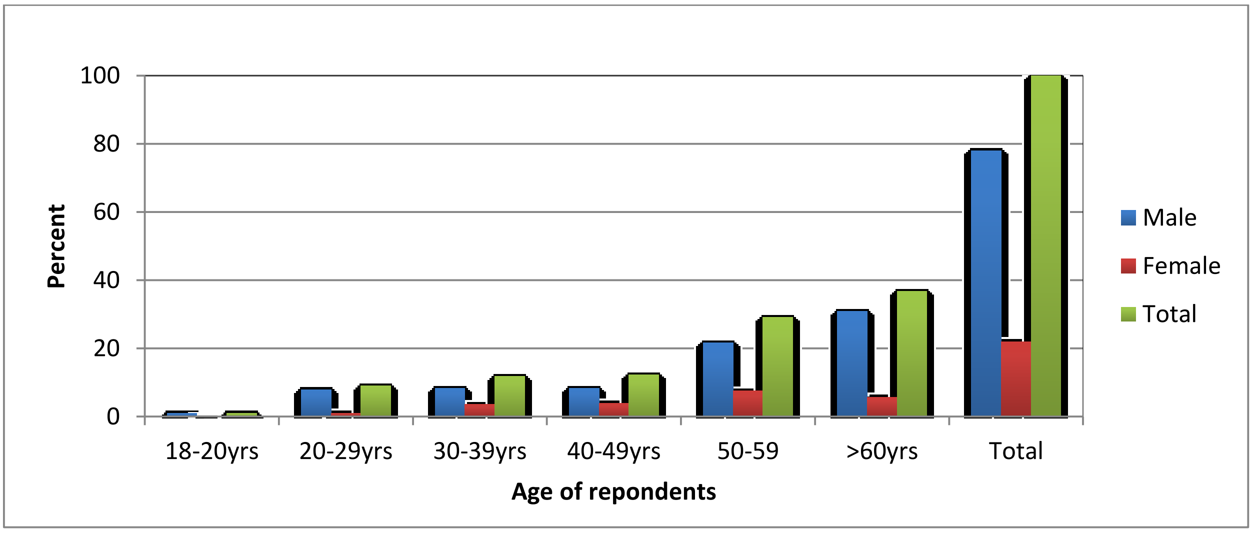


Figure 5-10: Age and gender of respondents

5.3.3 Respondents marital status

The greater part of the respondents are married, about 63 %, and about18% are widowed, followed by about 17% who are single, and 1.4% are either divorced or separated (see Figure 5.11). From this, it is evident that most of the farmers live as families that are mainly headed by males.

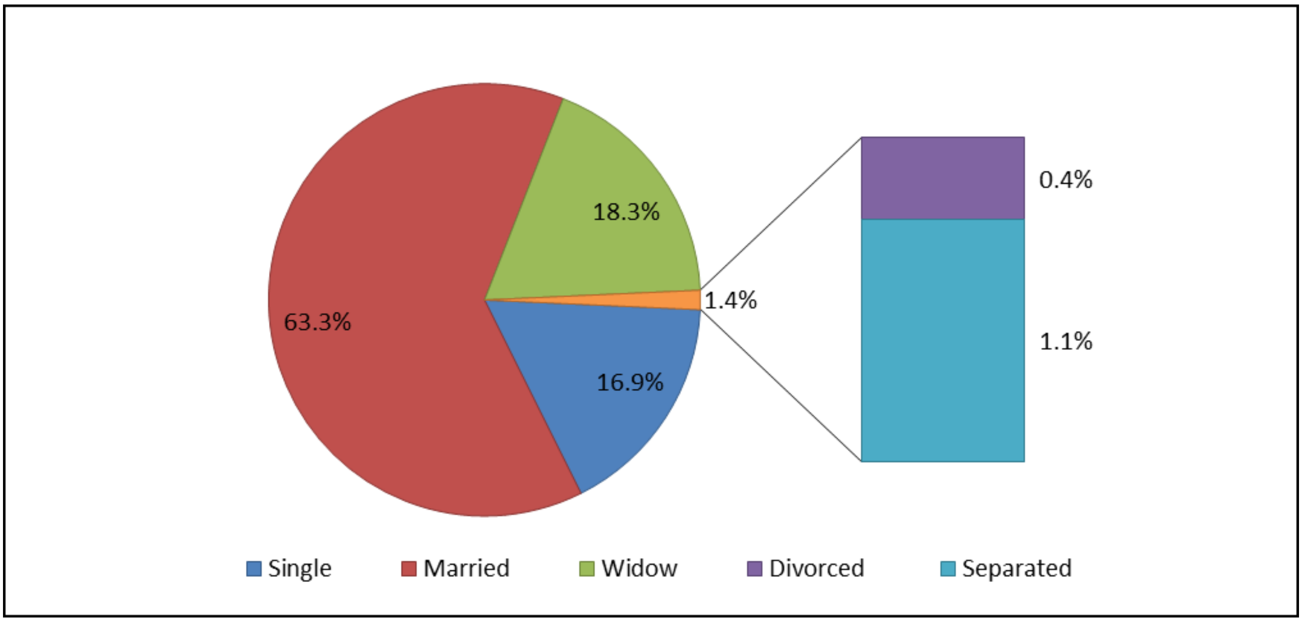


Figure 5-11: Marital status of respondents

5.3.4 Household sizes for respondents

With regard to household size, the majority of the households have families of sizes of 6 to 10 persons (45%), followed by small households of 1 to 5 persons (39%), then households of 11 to 15 persons (30%), and lastly households of sizes 16 to 20 persons (5%). There was no household that had over 20 persons (see Figure 5.12). From these results, it is evident that a larger proportion of households (74%) range from 1 to 10 persons per household.

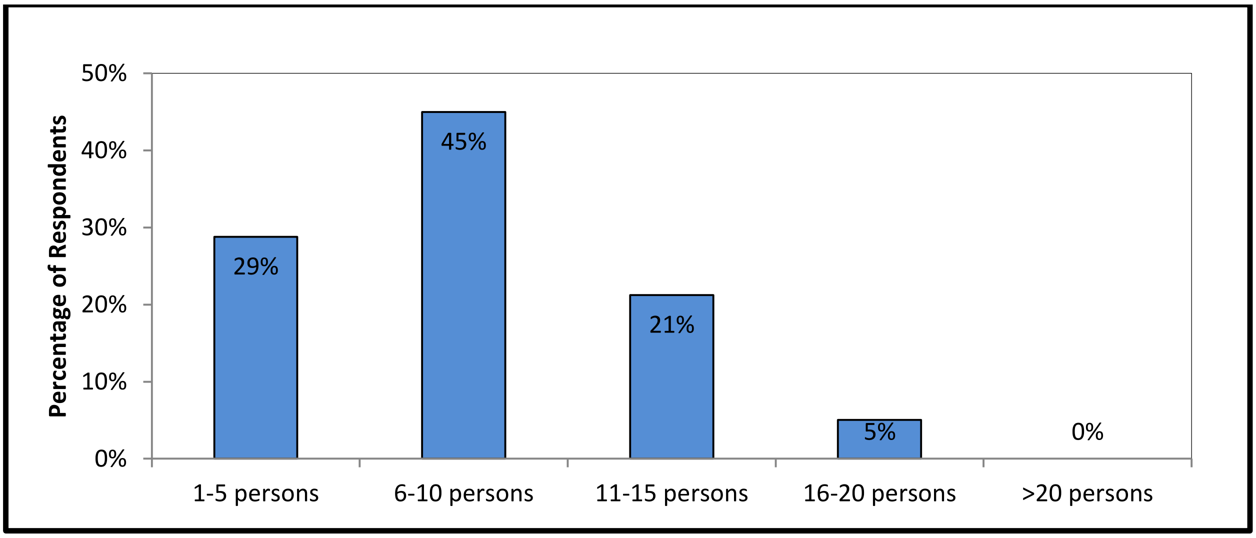


Figure 5-12 : Household size for the respondents

5.3.5 Respondents Educational level

The respondents' educational level, is shown in Figure 5.13, and is dominated by farmers who have Primary education (30%), followed by those without any formal education (22%), and those with High School education (22%). Then by those with Secondary education (16 %), and lastly by those with tertiary education, (10%).

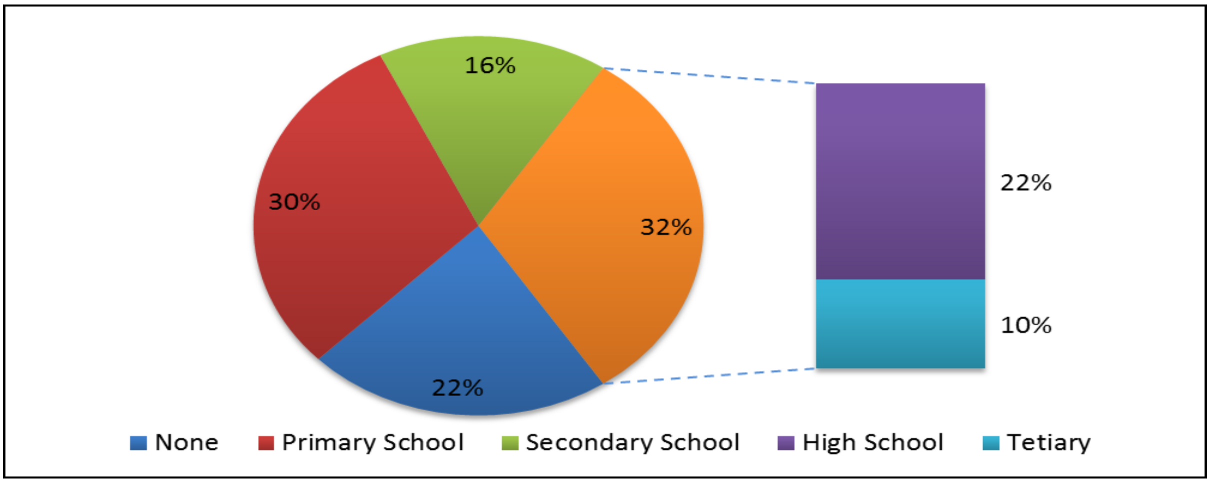


Figure 5-13: The education level of the Respondents

5.3.6 Employment status and main occupation

The analysis of results indicated that the majority of the respondents were not formally employed (79%), and only 21% were employed (see Table 5.11). Of the 21% respondents employed, 15% stated that they were formally employed, while 5% of the respondents stated that though they were employed, farming was their primary occupation, and 1% stated that their main occupation was running some businesses. With regards to those who stated they were not employed, 65% said farming was their primary occupation, while 9% stated that they were running some businesses. Only 5 % reported that they did not have any occupation though they were farming livestock.

Table 5-11: Cross-tabulation of employment status against occupation

Primary Occupation	Employed per occupation		Total
	Yes	No	
Employed	15	0	**15**
Farming	5	65	**69**
Business	1	9	**10**
No Occupation	0	5	**5**
Total	**21**	**79**	**100**

5.3.7 *Respondents main farming activities*

Besides rearing livestock, the respondents were engaged in other farming activities. All the respondents indicated that besides rearing animals, they also grow crops (Figure 5.14). Of the crops grown, 43% of the respondents indicated that they are engaged in grain crop (maize or sorghum) farming; while about 27% are engaged in mixed-crop farming (grain and or vegetables and or cotton and or sugarcane), 14 % only farm vegetables, and lastly 8 % only grow sugar cane or cotton. From this, it was evident that the livestock farmers in the Lowveld of Eswatini practise mixed farming; they rear livestock and also grow crops. Such farmers can be called agro-pastoralists.

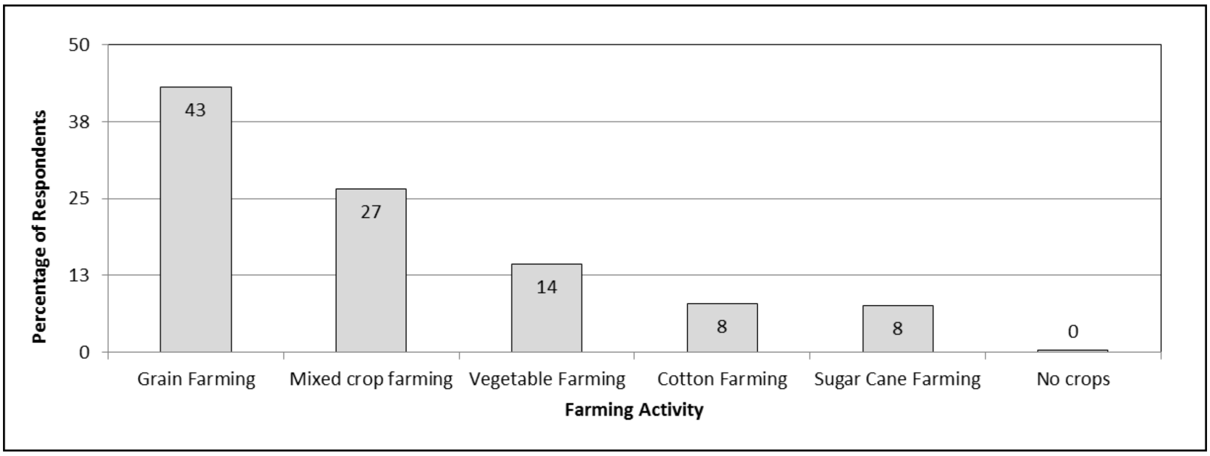


Figure 5-14: Other farming activities of the respondents

5.3.8 *The significance of livestock farming to the Respondents*

To comprehend the economic significance of livestock farming to the respondents, they were asked to rate livestock farming as their source of income on a scale. The results (see Figure 5.15.) indicate that 5 % of the respondents indicated that livestock farming is not an income source, and they rear livestock for other reasons. Nineteen percent (19%) of the respondents pointed out that livestock farming was a minor source of income; 37 % indicated that it was a moderate source of income; 54% indicated it was a major source of income; and 4 % indicated it was their only source of income.

From these results, it is obvious that most of the livestock farmers in the Lowveld of Eswatini generate fair income from their livestock. In fact, very few farmers keep livestock for other uses besides using it as a source of income.

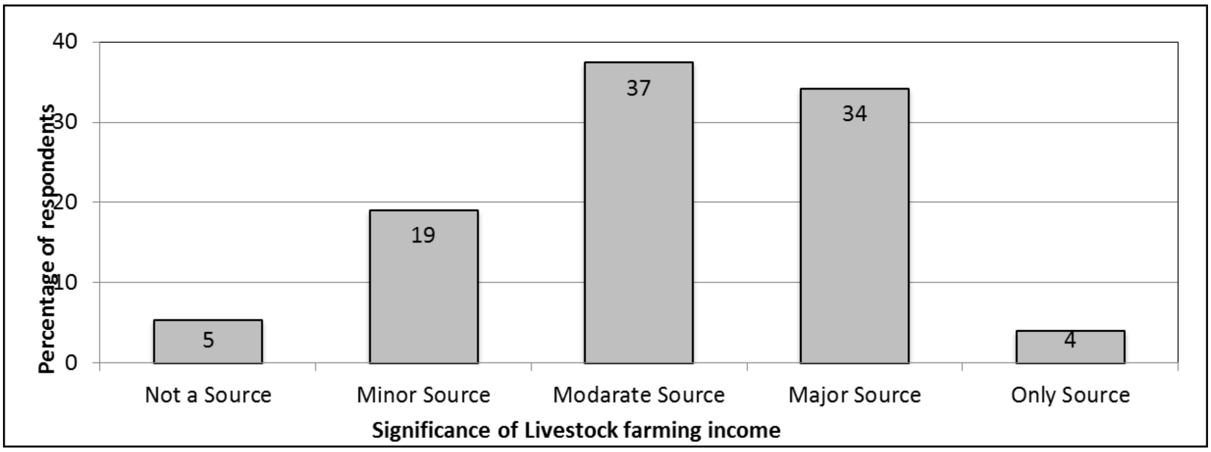


Figure 5-15: Significance of livestock farming income to farmers

5.3.9 Respondents years keeping livestock

The results (see Figure 5.16) show that a greater part of the respondents (37%) have been rearing livestock for more than 25 years, followed by those keeping livestock for 11-15 years (20%), then by those keeping livestock for 21-25 years (14%), and by those keeping livestock for 6-10 years (13%), then those keeping livestock for 0-5 years (11%), and lastly farmers keeping livestock for 16-20 years (6%). From this figure, it is evident that there are two peaks in the years of keeping livestock, those rearing livestock for over 25 years and those between 11 and 15 years. The increase in livestock keeping years was found to significantly correlate (0.01) with the age of the farmers.

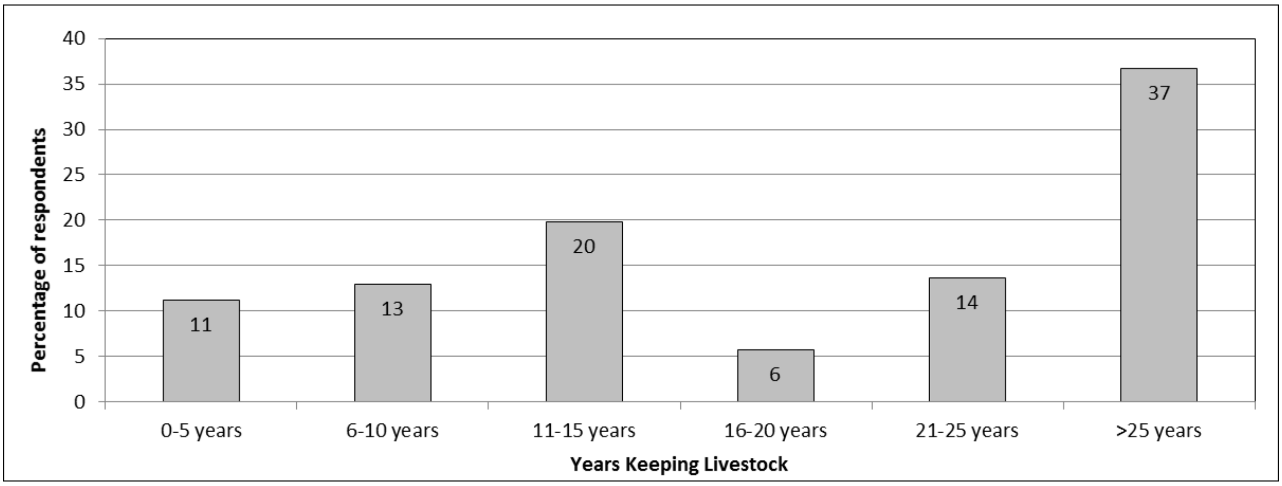


Figure 5-16: Farmers years rearing livestock

5.3.10 Farmers' reasons for rearing different livestock

When the farmers were asked about the reasons for rearing the livestock types they reared, their responses in percentages were as follows: the cattle farmers' main reasons for rearing cattle were mainly for a source of income (68%), and a source of wealth (25%), with self-consumption and customs being negligible (4%), respectively. The goat farmers' reasons for rearing goats were mainly for a source of income (76%) and a source of wealth (21%), with self-consumption being negligible (3%). There were few farmers rearing sheep, and their response for keeping these animals was mainly as a source of wealth. Chicken rearing tends to be mostly for subsistence living, where 83% of the farmers said they keep chicken for self-consumption and 8% raised chickens as a source of income or for wealth, respectively (see Table 5.12).

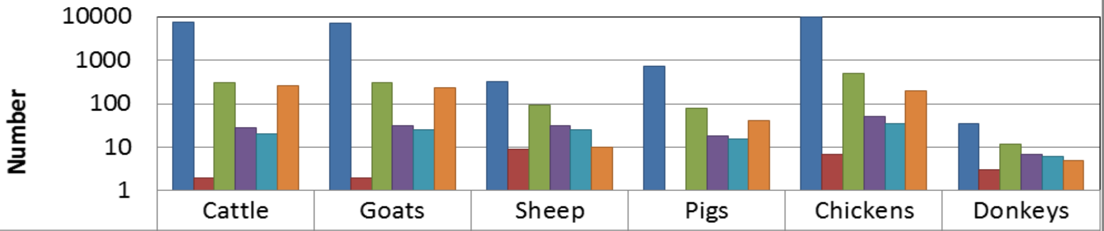
Table 5-12: Main reason for rearing each livestock type

Reason for rearing in %	Source of income	Self-consumption	Success or wealth	Customs	Other reasons
Cattle	68	4	25	4	0
Goat	76	3	21	0	0
Sheep	0	0	100	0	0
Pig	43	0	57	0	0
Chicken	8	83	8	0	0

5.3.11 Statistics of livestock owned by the respondents

Out of a total of 278 respondents, it was evident that the farmers kept either one or many types of livestock, and the mix varied from farmer to farmer. The summary for respondents indicated that cattle rearing was the most common, done by 254 (91%) farmers; followed by goat rearing carried out by 227 (82%) of the farmers. Next was poultry reared by 196 (71%) of the farmers, and this was trailed by pig farming done by 41 (15%) of the farmers, followed by sheep rearing by 10 (4%) of the farmers, and lastly was rearing of donkeys done by 5 (2%) of the farmers (Figure 5.17).

The herd size for cattle kept by these respondents ranged from 2 to 300, with a mean herd size of 29 cows, and a median herd size of 20 cows. For goats, the herd size ranged from 2 to 300, and a mean herd size of 31 and a median herd size of 25. The sheep herd ranged from 9 to 90 sheep per farmer, and an average herd of 32 and a median herd size of 25 sheep per farmer. Pigs ranged from 1 to 80 per farmer, and a mean herd of 18 and a median of 15 pigs per farmer. The chicken flock sizes ranged from a minimum of 10 to a maximum of 500 birds with a mean flock size of 50 chickens, and a median of 34 chickens per farmer. Lastly, the donkey herd ranged from 3 to 13 donkeys per farmer with a mean herd of 7 donkeys and a median of 6 donkeys per farmer, (Figure 5.17).

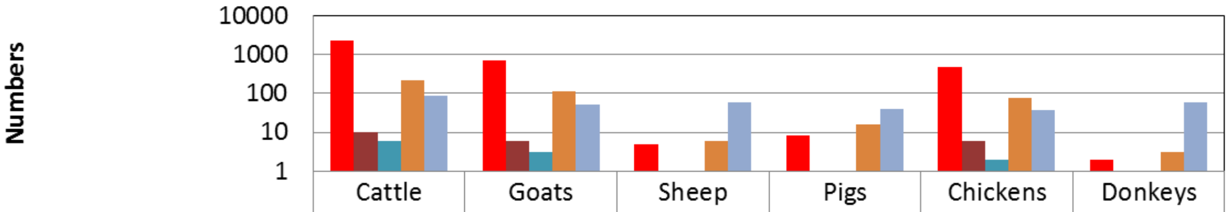


	Cattle	Goats	Sheep	Pigs	Chickens	Donkeys
Sum	7273	7032	316	731	9767	34
Minimum	2	2	9	1	7	3
Maximum	300	300	90	80	500	12
Mean	29	31	32	18	50	7
Median	20	25	25	15	34	6
No of respondents	254	227	10	41	196	5

Figure 5-17: Statistics of livestock owned by the Respondents

5.3.12 Livestock loses to a drought

The livestock farmers were requested to indicate the highest number of livestock they had lost to a drought, the results are summarized in Figure 5.18 below. These results, indicated that 87% of the cattle farmers reported they had experienced livestock losses to a drought, with an average loss of 10 cows (or a median of 6 cows) per farmer; Again, 50% of all goat farmers indicated that they lost on average 6 goats (median of 3 goats) per farmer. Whereas 60% of sheep farmers indicated they lost on average 1 sheep per farmer. While 39% of pig farmers reported to have lost on average 1 pig per farmer, 38% of poultry farmers reported to have lost 6 (median of 2) chickens per farmer. Lastly, 60% of donkey farmers reported to have lost 1 donkey per farmer.



	Cattle	Goats	Sheep	Pigs	Chickens	Donkeys
Sum	2225	698	5	8	468	2
Mean	10	6	1	1	6	1
Median	6	3	1	0	2	0
No of respondents	221	113	6	16	75	3
As a % of respondents	87	50	60	39	38	60

Figure 5-18: Highest Number of livestock loses in a drought

5.3.13 Reliability test results

The questionnaire had four sections which were tested for reliability using Cronbach's alpha which ranges from 0 to 1, where 0 represents the presence of full error and 1 represents total absence of error. A Cronbach's alpha value of 0.70 or greater is regarded as satisfactory (Radhakrishna, 2007). The reliably test results for each section are as follows and are regarded as satisfactory:

- Sources of climate information used 8 items ($\alpha = .709$)
- Climate indicators used 5 items ($\alpha = .701$)
- Climate change impacts measures used 10 items ($\alpha = .721$)
- Adaptation measures used by farmers consisted of 24 items ($\alpha = .805$)

5.3.14 Summary Biographical data of respondents

The biographical data of the sampled population obtained using the questionnaires provides the contextual setting and socio-economic background of the study participants. The results cover gender, age, marital status, educational level, employment status, occupation, and household size. The results indicate that 78% of the respondents are males, and female respondents constituted the remaining 22%. With regard to age, most of the respondents (66%) were above 50 years, 24% for ages 30 to 49 years, and 10% for the ages 18-29years. Most of the respondents (62 %), are married; 18 % are widowed; 17 % are single, 2% divorced or separated. For household size the majority (74%) of households have 1-10 persons of which 45% of households have (6-10 persons); and 30% of households have 11-15 persons. The educational level of the respondents is dominated by farmers who have primary education (30%); followed by those without any formal education (21.9%); and those with high school education (21.6%). Those with secondary education constituted by 16.5%; and lastly by those with tertiary education (10 %). Farmers with no education are the least of the respondents (9.7%). The majority (79%) of the farmers are not employed and only 21% are employed.

The crops grown by the farmers include grain crop (maize or sorghum) grown by 43% of the respondents; mixed crop farming done by 27%, while 14% grow only vegetables, and 8% grow only sugarcane or cotton. The results indicate that most (51%) of the respondents have been rearing livestock for more than 21years; 26% have been keeping livestock for 11-20 years; and 23% have been keeping livestock for 0-10 years. The majority (>68%) of the farmers raise cattle and goats as an income source, while they keep sheep as a symbol of wealth. Most farmers raise chicken for self-consumption.

Out of the 278 livestock farmers interviewed, the summary for respondents indicated that 254 (91%) raised cattle, 227 (82%) reared goat, 196 (71%) raised chickens, 41 (15%) raised pigs, 10 (4%) farmed sheep, and 5 (2%) raised donkeys. The average head sizes was as follows: 29 for cattle, 31 for goats, 32 for sheep, 18 for pigs, 50 for chickens, and 7 for donkeys. Lastly, with regards to livestock deaths due to drought and climate variability or change, 87% of the cattle farmers lost cattle with an average of 10 cows per farmer; 50% of goat farmers with an average of 6 goats per farmer; 60% of sheep farmers with an average of 1 sheep per farmer; 39% of pig farmers with an average of 1 pig per farmer; 38% of chicken / poultry farmers with an average of 6 chickens per farmer; and 60% of donkey farmers lost on average1 donkey per farmer.

5.4 Farmers perception of climate

Examining and understanding farmers' climate change perception is essential in understanding their adaptation responses or actions. Weber (2010) states that the general perception for mankind of climate change and variability is usually based on their observations of climatic variables that affect their lives. For this study, questions about perceived changes of temperature, average rainfall, incidences of hot and cold days, and incidences of the drought, wind and floods over lengthy period of time were used to gauge the farmers' perception of climate change.

The results of the farmers perceived changes to selected indicators of climate change or variability are shown in Figure 5.19. All the farmers perceived temperatures to have risen; 65% perceived a significant increase, and 35% an increase in temperatures, with no farmer perceiving other options. When quizzed about hot days (heat wave), the response was also similar for temperature where 55% of the farmers perceived a significant increase in hot days. With regard to drought severity and frequency, the farmers generally perceived an increase in drought severity and drought frequency where 53% noticed a significant increase in severity, and 38% and increase in severity, with only 5% stating that there has been no change to severity, and 4% stating a decrease in droughts severity. While 44% of the farmers perceived drought frequency to have significantly increased, 45% perceived an increase in frequency, and 4 % noticed no change, and 6% a decrease in drought severity. For wind, 69% of the farmers perceived an increase, 52% and17% significant increase in winds, with only 17% perceiving no change in winds, and 13% a decline in winds.

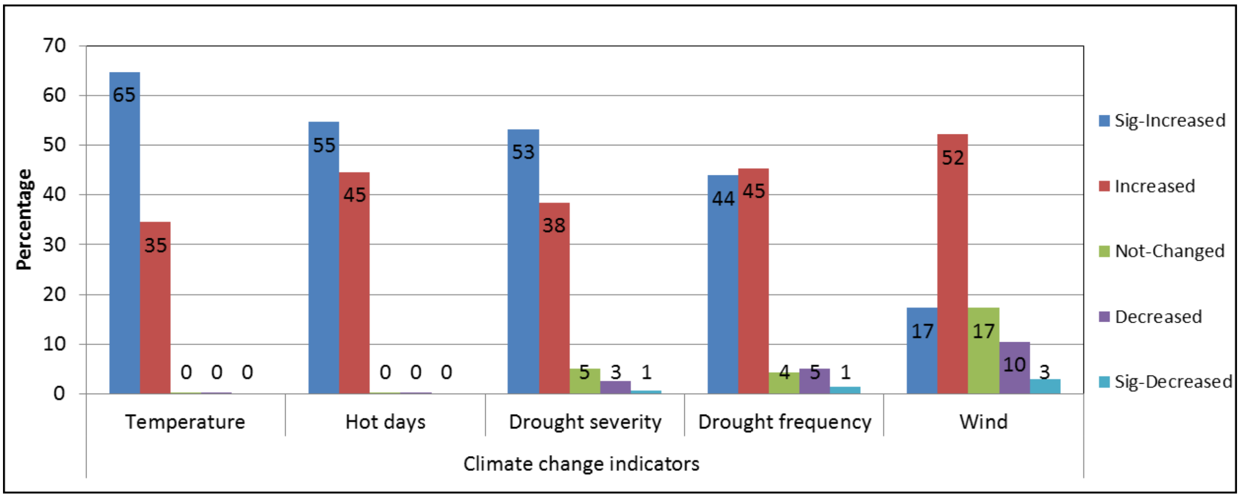


Figure 5-19: Farmers perception (as increasing) to climate indicators

The farmers' perceived changes (mostly a decrease) to selected indicators of climate change or variability are shown in Figure 5.20. The majority (54%) of the farmers perceived that floods have decreased, of which 35% perceived a decrease; 19% perceived that floods have significantly decreased, with 25% perceiving an increase; and only 19% perceiving no change. Half (50%) of the farmers perceived that cold days had decreased: 37% for decreased and 13% for significantly decreased. While 35% of farmers perceived an increase in cold days, 25% of these were for an increase, and 10% for a significant increase, with only 15% perceiving no change.With regard to rainfall, rain days and the rain season, the majority of the farmers perceived a decrease with 59% perceiving that rainfall had decreased. 63% perceived a decrease in rain days, and 47% perceived a decrease in the rainy season. These were followed by 33% of farmers who perceived a significant decrease in the rainfall, and 28% of these perceived that there was a significant decrease in rain days, while 24% perceived that there was a significant decrease in the rain season. Less than 10% of the farmers perceived that the rainfall and rain days had either remained unchanged, had increased, or had significantly increased. About 23% of the farmers perceived that the rainfall season had not changed with about 6% perceiving an increase in the season.

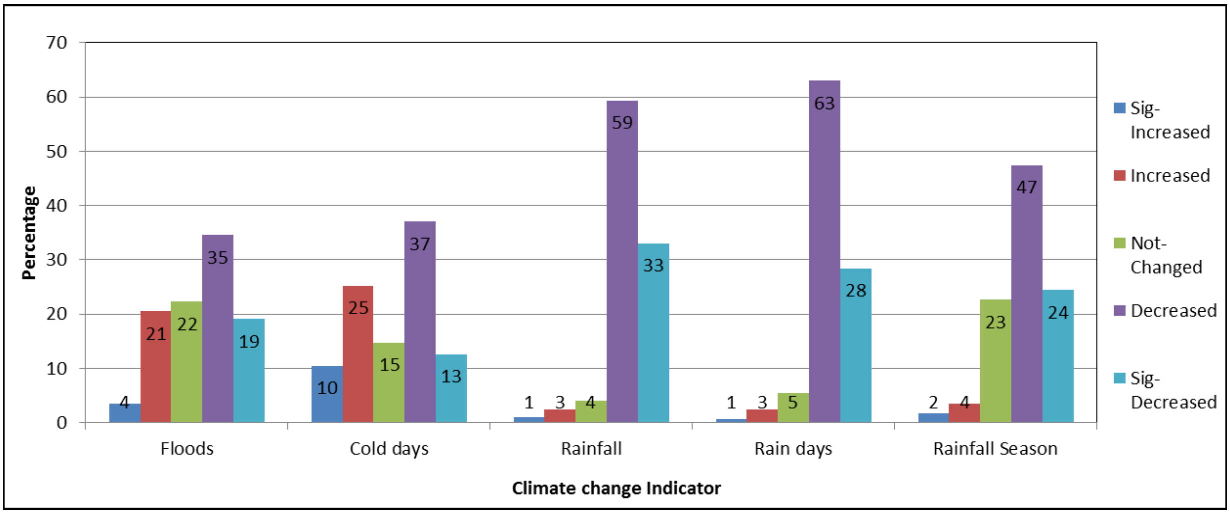


Figure 5-20: Farmers perception (as decreasing) of selected climate indicators

5.4.1 Farmers temperature and rainfall perceptions

A cross tabulation of the farmers' perception towards temperatures (long-term) was done with constituencies (location) in which the farmers reside, and the outcome is presented in Table 5.13. The outcome revealed that there was a wide range of variance of their perception of temperatures in relation to location. A Chi-square (X^2) Test of Independence was carried out on the cross tabulated data to examine the relationship between perception of temperature changes and the areas in which the farmers live. The relation between these variables was significant, X^2 *(27, N=278)* =79.289, *p<0.000.* These results indicate that farmers' perception of temperature is associated to the area they live in.

Table 5-13: Presentation of farmers' perception of temperature against the location

Location (Constituency)	Perception of Temperature				
	Sig-Increased	Increased	Not-Changed	Decreased	Total
Matsanjeni_south	10%	90%	0%	0%	100%
Somntongo	68%	29%	0%	3%	100%
Mandlangempsi	76%	22%	2%	0%	100%
Mhlangatane	75%	25%	0%	0%	20%
Mkhiweni	33%	67%	0%	0%	100%
Dvokodvweni	83%	17%	0%	0%	100%
Mpolonjeni	85%	15%	0%	0%	100%
Siphofaneni	33%	67%	0%	0%	100%
Gilgal	43%	57%	0%	0%	100%
Sithobela	77%	23%	0%	0%	100%
Total	65%	35%	0%	0%	100%

A similar cross tabulation of the farmers' perception of rainfall (long-term) and constituencies was conducted and the results (see Table 5.14.) indicated that in spite of the wide range of variance of the farmers' perception of rainfall, they generally perceived a decrease in rainfall. The Chi-square (X^2) Test of Independence was performed on the cross tabulated data to examine a relationship between the farmers' perception of rainfall received and the areas in which they live. The Chi-square Test indicated that a significant association exists between these variables, X^2 *(36, N=278)* =109.959*, p<0.000.* This result indicates that farmers' perception of rainfall is associated to the area in which they live.

Table 5-14: Presentation of farmers' perception of rainfall against location

	Perception of Rainfall					
Location (Constituencies)	Sig-Increased	Increased	Not-Changed	Decreased	Sig-Decreased	Total
Matsanjeni_south	3%	13%	20%	60%	3%	100%
Somntongo	0%	0%	3%	84%	13%	100%
Mandlangempsi	0%	2%	6%	53%	39%	100%
Mhlangatane	0%	4%	0%	57%	39%	100%
Mkhiweni	0%	0%	17%	83%	0%	100%
Dvokodvweni	6%	0%	0%	57%	37%	100%
Gilgal	0%	0%	0%	86%	14%	100%
Mpolonjeni	0%	0%	0%	69%	31%	100%
Siphofaneni	0%	0%	0%	83%	17%	100%
Sithobela	0%	0%	0%	20%	80%	100%
Total	1%	3%	4%	59%	33%	100%

Overall, for all the indicators used to ascertain the farmers' perception of climate change, the majority of farmers reported that they perceived a change in climate or climate indicator whereby temperature, hot days, drought severity, drought frequency, and wind were perceived to increase; while rainfall, rain-days, rain season, cold days, and floods were perceived to have decreased. Furthermore, the farmers' perceptions of long term rainfall and temperatures were significantly related to the areas in which they lived.

5.4.2 *Comparing farmers perceptions with meteorological data*

The farmers' perceptions of climate were assessed by asking them if they had noticed any changes in climatic variables over an extended period of time (20-30 years). Their responses were compared with the trends of climate data from the meteorological stations within the Lowveld of Eswatini. This approach is comparable with the approach adopted in some previous studies (Gbetibouo, 2009; Teye *et al., 2015).* The farmers' perceptions of temperature were that temperatures have increased. Given that the Lowveld of Eswatini extends over a large area, there are two meteorological stations and one rainfall measuring station within the area. The temperature data from these stations were analysed in detail in Section 5.2, and the significant results summary results are as follows:

5.4.3 Comparing perceptions of temperature

In an effort to evaluate the farmers' perception to climate, the responses were grouped into regions based on their proximity to the meteorological station, and as such, the Lowveld of Eswatini was divided into three regions. The farmers' perceptions to temperature are presented in Figure 5.21. When evaluating their perceptions against the meteorological data, it is evident that for those from the northern part of the Lowveld, using Mhlume temperatures as a proxy, their annual temperatures have declined (by 0.5 ^{o}C), with the exception of the month of June. This does not fully support the perception that temperatures have increased with the exception of the month of June whose temperatures have significantly increased by 1.3 ^{o}C over a 31 year period.

Whereas temperatures in the central southern regions parts, using the Big Bend weather station as a proxy, the meteorological data is in agreement with the farmers' observations, with annual mean maximum and minimum temperatures all increasing significantly over the 31 year period .

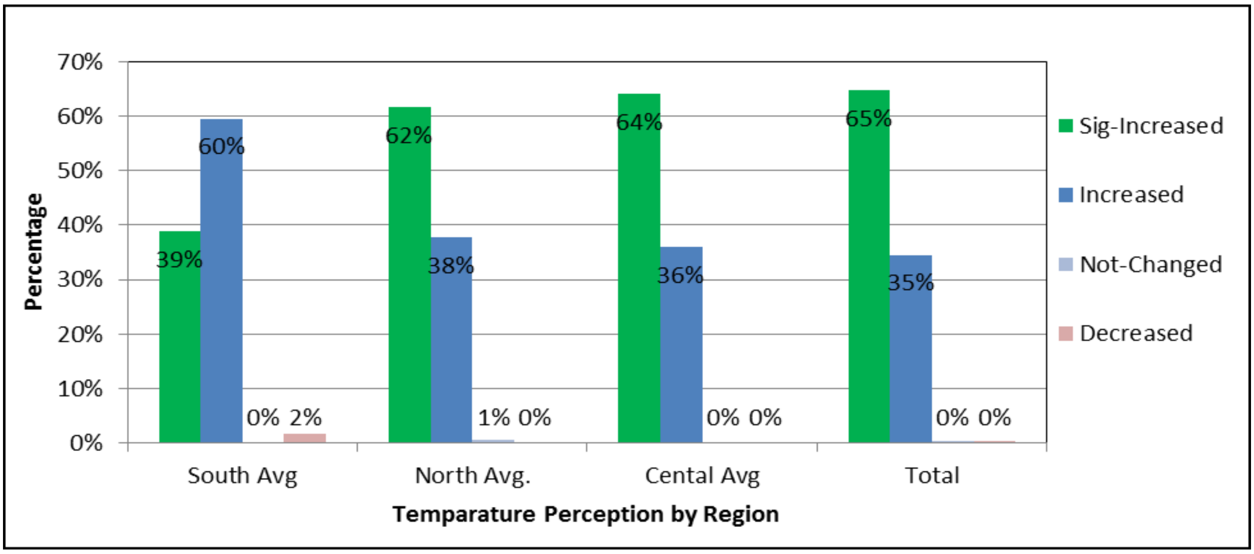


Figure 5-21: Farmers temperature perception by region

5.4.4 Comparing perceptions of rainfall

With regard to rainfall, three meteorological stations were used to compare the farmers' perceptions, and these are: Big Bend, Sithobela and Mhlume. The analysis of the rainfall data revealed there was an insignificant change in Big Bend's annual rainfall; however, on a monthly basis, the month of June rainfall decreased ($p \leq 0.1$). Also there was an insignificant change in Sithobela's annual or seasonal rainfall over 31 years; however, on a monthly time-scale there was a significant decrease in June's rainfall ($p \leq 0.01$), and October's rainfall ($p \leq 0.1$). While Mhlume's annual rainfall significantly ($p \leq 0.05$) declined, also the summer season rainfall decreased; likewise, the rainfall for the month of February decreased. The comparison of the farmers' perceptions of rainfall by region (see Figure 5.22), and the actual rainfall data indicated that there is an overwhelming perception that rainfall decreased, with very few farmers perceiving no change or an increase in rainfall. Although the significant decline does not correlate with annual rainfall, it does with some months or seasons, and this change can influence farmers' perception of rainfall.

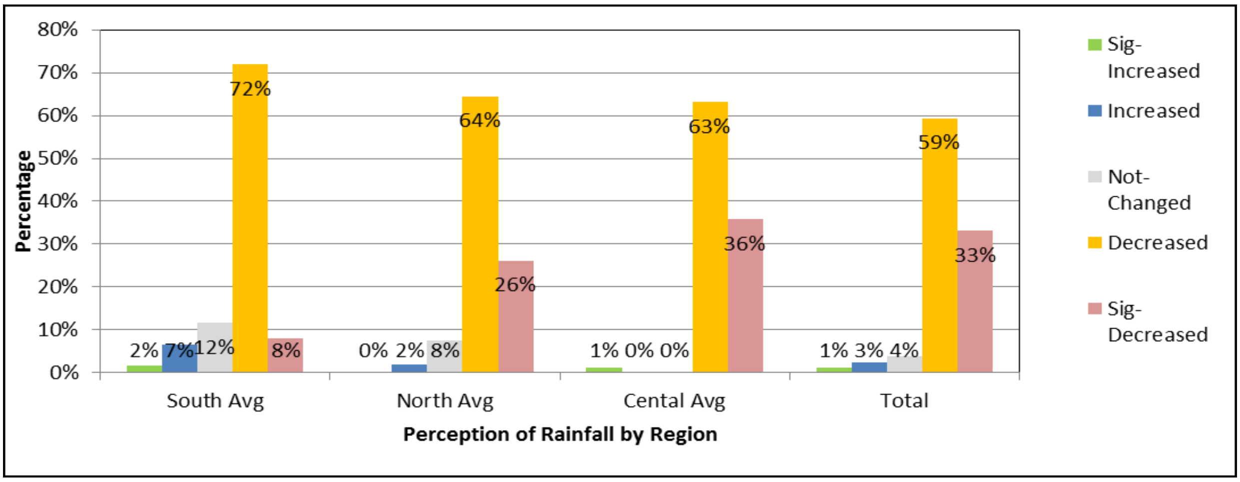


Figure 5-22: Farmers' perception of rainfall by region

5.4.5 *Summary on farmers perceptions*

The conclusions that can be drawn about the farmers' perceptions towards climate variables such as temperature and rainfall and drought are: Firstly, farmers' perception of climate differs with location. This observation is similar with that of other scholars (Maddison, 2007; Gbetibouo, 2009; Teye *et al.,* 2015) who concluded that perceptions of climate change tend to vary spatially. Secondly, the farmers' perception that temperature increased in the central and southern parts of the study area corresponds with observed temperature changes from meteorological data (using Big Bend as a proxy), and these outcomes are comparable perceptions with farmers around Africa (Maddison 2007; Gbetibouo 2009; Fosu-Mensah *et al*., 2012; Zampaligré *et al*., 2014). However, for areas in the northern part (using Mhlume as a proxy) of the Lowveld, the temperatures actually declined over the 31 year period with the exception of the month of June whose temperatures increased. The inconsistency between farmers' perception of temperature and the climatic data might be explained by an observation by Ovuka and Lindqvist (2000), who state that scientists often consider climate data at dissimilar time-scales than those used by farmers which include crop growing season, causing likely discrepancies in farmers' perceptions and observed data.

There was no marked decline in yearly rainfall for all areas; however, the rainfall amounts in certain months or seasons declined significantly, while the farmers' perception was of reduced rainfall. This observation can be explained by a finding by Blench (2006), that observed a comparable divergence between public perception on rainfall and the meteorological data; and this variance was accredited to variation in scientific computation of rainfall trends and drought where the scientific focus is on meteorological drought while farmers focus is on agronomic drought.

Lastly, the majority of the farmers perceived an increase in drought severity and drought frequency over time, this perception is in line with empirical findings by Tfwala *et al*. (2020), who concluded that, in Lowveld, there was a spatial and temporal increase in droughts prevalence and severity over time.

5.5 Farmers awareness of climate change and access to information

Climate change awareness of is paramount for determining effective implementation measures for its adaptation. Hence, understanding the farmers' sources of information is vital in understanding the knowledge they have. The results indicated that the majority of farmers (89%) who were quizzed on their knowledge of climate change indicated that they understood what it meant and only 11% did not. Of these farmers, 83% stated they knew the problems associated with climate change, and only 17% said they were not aware of such problems (see Figure 5.23). These results on awareness are consistent with the findings of other scholars such as Ado *et al.,* (2019) who reported awareness of 84.4 % while studying farmers' awareness and perception in Niger. Likewise, Ajayi (2014) reported that 86.11% of farmers in the Niger Delta region of Nigeria were aware of climate change. Also, Mandleni and Amin (2011), while studying farmers in South Africa, reported that 85% of the farmers studied were knowledgeable about climate change.

When asked if they do have access to climate change information, 78% stated that they do while 22% said they do not. Finally, 76% of the farmers indicated they had access to climate change information relevant to livestock farming.

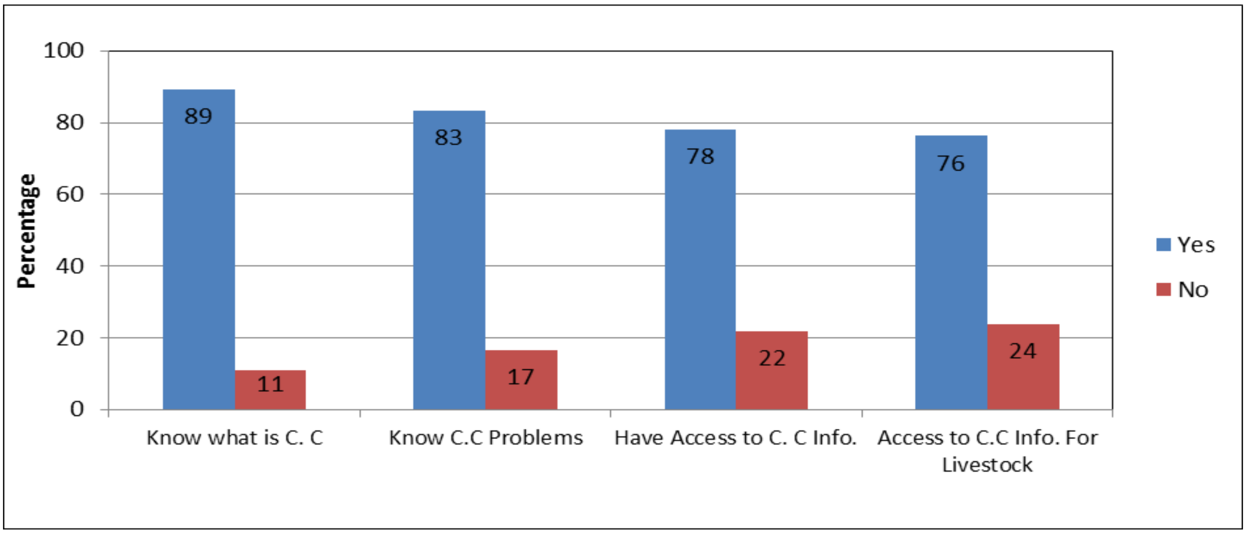


Figure 5-23: Farmers awareness of climate change and access to climate information

5.5.1 Link between climate change knowledge and socio-demographic variables

A cross-tabulation was performed to examine the connection between socio-demographic variables and the farmers' knowledge of climate change. The socio-demographic variables considered were age, education level, household size, income from livestock, years for livestock farming, marital status of head of household, the constituency (location), and gender. From the cross tabulation of these variables, several variables were significantly related to farmers knowledge of climate change and these were: age *($p < 0.1$),* education *($p < 0.01$),* size of the household *($p < 0.01$),* and the amount of income the farmers derive from livestock farming ($p < 0.1$), see Table: 5.15.

Table 5-15: Link between climate change knowledge and socio-demographic variables

Variable		Knowledge Of Climate Change			Statistics		
		Yes (%)	*(No)%*	Total (%)	X^2 =	*df* =	*p* =
Age							
	Young (20-29)	10	0	10	4.674	2	0.097*
	Adults(30-59)	49	5	53			
	Aged(>60)	31	6	37			
	Total	89	11	100			
Gender							
	Female	20	2	22	0.546	1	0.460
	Male	69	9	78			
	Total	89	11	100			
Education level							
	Little or Non	42	10	52	19.299	1	0.000***
	Educated	47	1	48			
	Total	89	11	100			
Constituency (location)							
	North	35	6	41	3.587	2	0.166
	Central	35	3	37			
	South	20	2	22			
	Total	89	11	100			
Marital Status							
	Married	56	7	63	0.163	1	0.686
	Other	33	4	37			
	Total	89	11	100			
Household Size							
	Small	21	5	26	7.233	1	0.007***
	Large	68	6	74			
	Total	89	11	100			
Livestock derived Income							
	Not a Source	5	0	5	8.969	4	0.062*
	Minor Source	17	2	19			
	Moderate Source	33	4	37			
	Major Source	32	3	34			
	Only Source	3	1	4			
	Total	89	11	100			
Years Farming Livestock							
	0-10yrs	17	1	18	4.098	2	0.129
	11-20yrs	24	1	25			
	>20yrs	49	8	56			
	Total	89	11	100			

5.5.2 The major sources of climate information used.

The farmers' climate change perceptions correlate with their knowledge and adaptation choices Nguyen *et al.* (2016). Therefore, availability and accessibility to information on climate is a key determinant of the extent of farmer awareness and understanding of climate change. The farmers' major information sources on climate are shown on Figure 5.24: 1) The radio which is the best information source on climate and used by about 81% of the time by farmers; 2) The television (with a mean use of 68%); 3) The family and neighbours (with a mean use of 59%) who share information with the farmers; 4) The newspapers (with a mean use of 58%); 5) Other farmers (with a mean use of 56%); 6) Social networks or media (51% mean usage); 7) Formal government extension services (51% mean usage); and 8) Farmers Co-operatives or entities (45% mean usage).

These determinants are comparable to those conveyed by Ajayi (2014) with regard to radio, where it was revealed that 81.4% of respondents obtained communication on climate change primarily from radio. However, this differed for the other sources where television, social media or farmer associations were reported by less than 5% usage each.

From these statistics, it is evident that based on usage trends, the dominant official channels used by the farmers to receive information are radio, television, newspaper, social media, and extension services. Based on this analysis, it is also evident that social circles like family and neighbours, also play a major role in information dissemination. Therefore, policy interventions on climate change should target these channels.

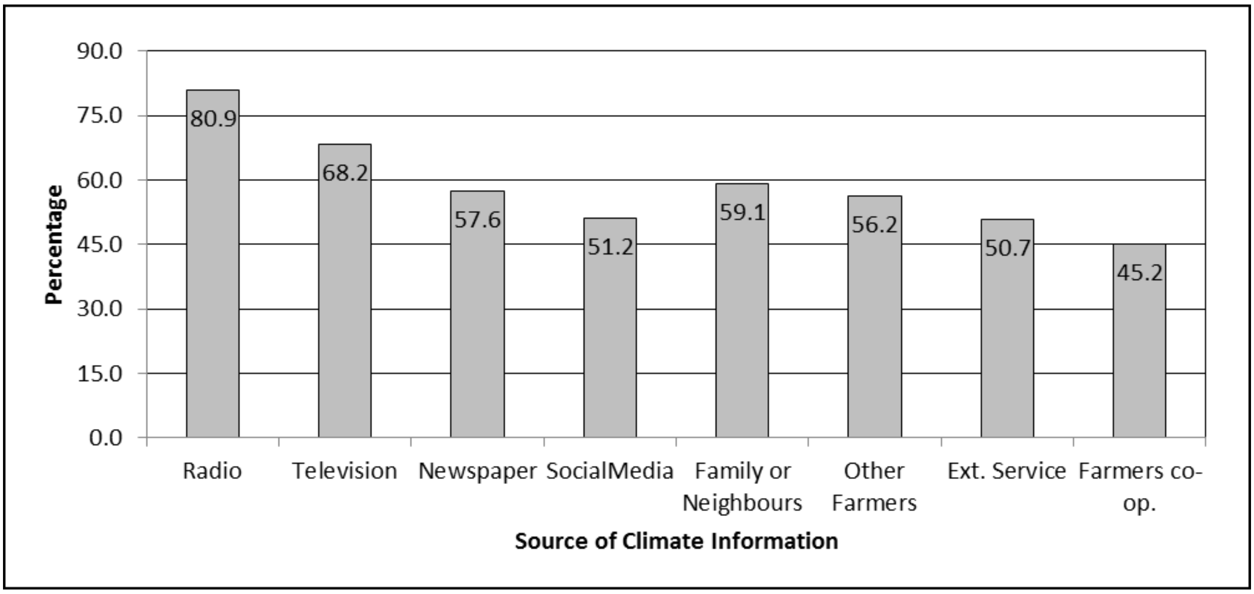


Figure 5-24: Climate Information source by usage

5.6 Climate change impacts on the farmers activities

After examining the farmers' perceptions of climate change, their observations of climate change impacts on their livelihood, activities were solicited. These livelihood activities include both household and livestock farming activities. The results are discussed below.

5.6.1 Climate change impacts on household activities

Overall, the farmers indicated that climate change or variability had detrimental impacts on all their household activities. The only exception was the impact on family health where 50% of the farmers reported a decrease (12% significant decrease and 38% decrease), while the other 50%

either reported no change (32%) or increased 16% or a significant increase (1%) in family health (see Figure 5.25). The farmers highlighted that climate change had detrimental impacts on their crop yields, and this was reported by 92% of the farmers (69% significant decrease and 23% decrease), while for their household income, 84% of the farmers reported a decline (30% significant decrease and 54% decrease). The majority of farmers (73%) reported a decline in the accessibility of domestic water, of which 24% reported a significant decrease and 49% reported a decrease. Lastly, the majority (59%) of the farmers reported an increase in diseases amongst their family members (15% significant increase and 44% increase).

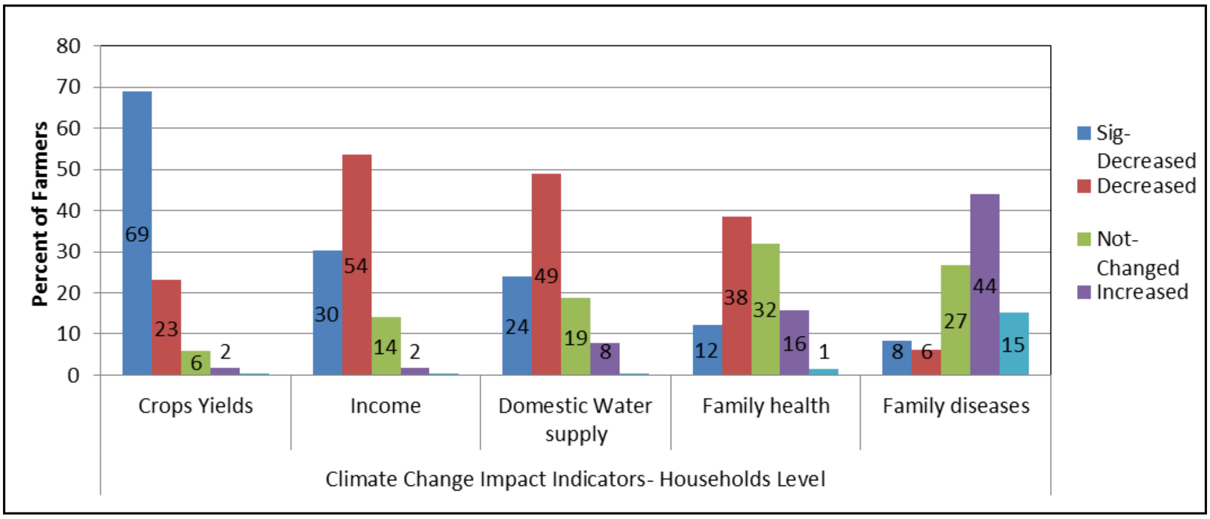


Figure 5-25: Perceived Impacts of climate change on several livelihood activities

The perceived impacts on all their household activities varied with location as outlined in Figure 5.26

These findings are similar to findings by Popoola *et al.* (2018) study on small-holder farmers' perceptions on climate change impacts in South Africa's Eastern Cape Province, that revealed that farmers perceived a rise in temperatures and a decline in precipitation, resulting in reduced crop quality and yield, water scarcity, an upsurge in pest infestations and diseases, and farm income earnings.

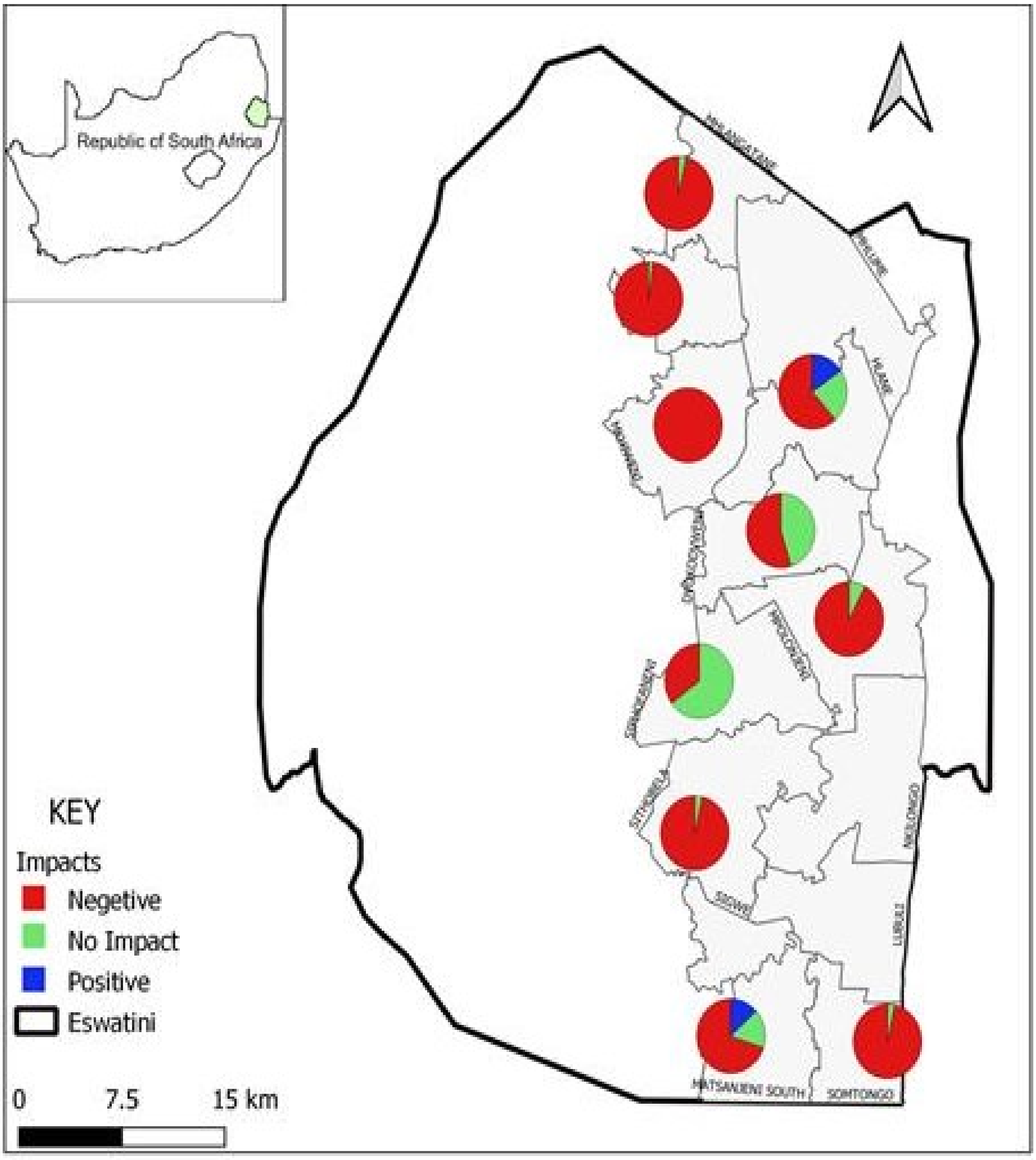


Figure 5-26: Spatial rendering of climate impacts on household

5.6.2 Climate change impacts on livestock farming

When quizzed on the impact of climate change or variability on livestock farming, the majority of the farmers (78%) stated that climate change had adverse impacts on their livestock (see Figure 5.27). The farmers (78%) reported an observed decline in livestock farming attributable to climate change. This value was found to be very comparable with that the 79.5% farmers who reported to have lost cows in a drought where the summary statistics were: largest herd size lost due to drought (N = 221, 79.5%, mean = 11.1 cows.

For each livestock farming activity, the farmers reported as follows: 1) With regard to grazing 88% of the farmers stated that climate change had decreased their grazing (of these 64% stated they experienced a significant decrease, and 24% a decrease in grazing). 2) 89% of the farmers noted a decline in water available for livestock (of these 36% reported a significant decrease, and 53% a decrease). 3) 79% of the farmers reported a decline in milk production (21% significant decrease, and 58% decrease). 4) 71% of the farmers stated they had noticed a decline in birth rates of their livestock (of these 20% perceived a significant decrease in birth rates, and 51% a decrease). 5) 85% of the farmers reported that livestock pest and diseases had increased due to climate change (of these 19% reported a significant increase, and 67% reported an upsurge). 6) 71% of the farmers reported an upsurge in the death rate of livestock (of these 14% recording a significant increase, and 60% reporting an increase).

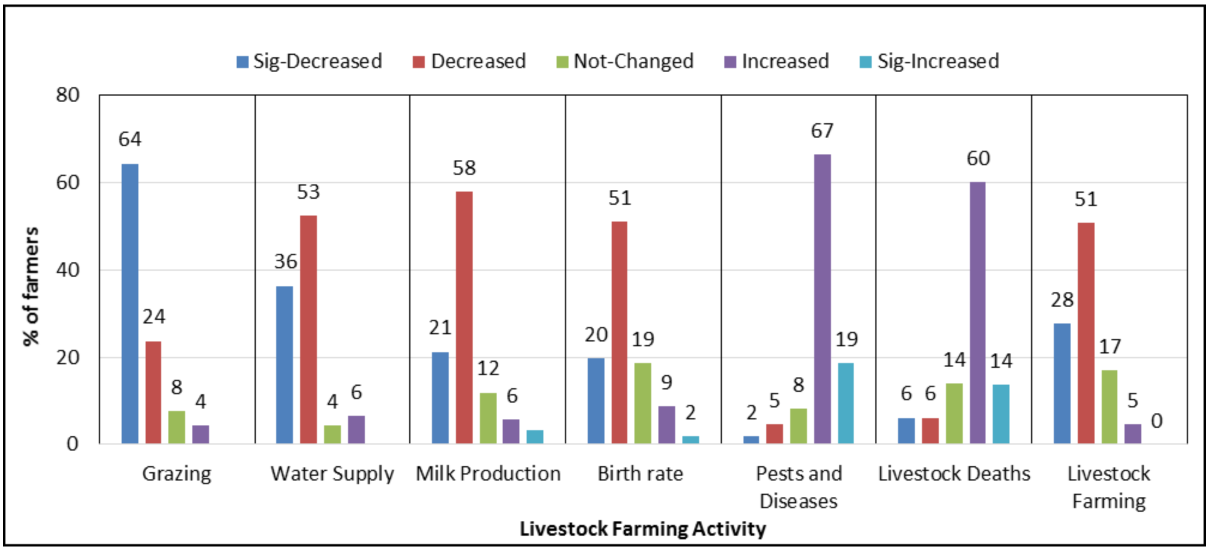


Figure 5-27: Impact on livestock farming activities

The reported impacts on livestock farming were subjected to spatial analysis, and it was found that they vary with location see Figure 5.28).

These results, to a certain extent, concur with those of a study on smallholder cattle farmers in Malawi that perceived that climate change resulted in an increases in pests (72%), a reduction in cattle feed consumption, reduced milk yields, reduced growth levels (reported by 70% of the farmers). A decline in milk production was reported by 79%, while about 40% reported a decrease in calving rates and an increase in calf and total cattle mortalities (Chingala *et al.,* 2017). The observation on mortalities is less compared to the results of the current study that was reported by 71% of the farmers.

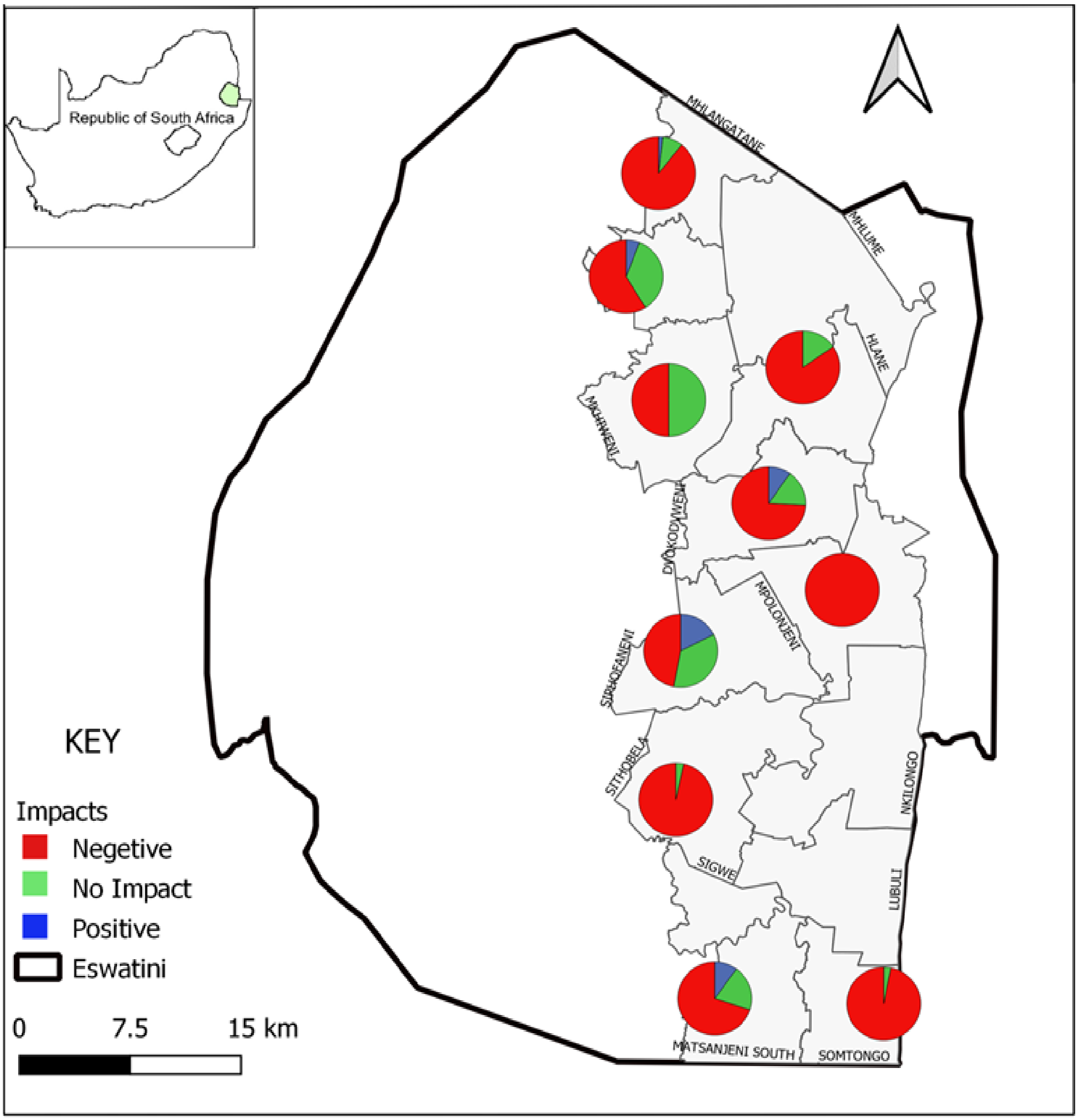


Figure 5-28: Spatial rendering of climate change impacts on livestock farming

5.7 Modelling the predictors of farmers perceptions

The farmers' perceptions of climate change were assessed by asking them if they have noticed any changes to certain climatic variables over a considerable period of time (20-30 years). To analyse these perceptions, comparability of the farmers' responses to actual meteorological data was done. Secondly, bivariate analysis that made use of cross-tabulations and Chi-square Tests to explore the associations between the farmers' perceptions of certain climate variables and some socio-demographic variables was used. Lastly, the study made use of Multivariate analysis that utilised the MNL Model to study the predictors of climate change perceptions. Before running the model, using the SPSS software version 20, the variables assumed to influence perception were checked for the presence of heavy correlation that is referred to as Multi-collinearity. To test for this, researchers use correlation coefficients cut-offs of 0.80 (Berry & Feldman, 1985). However, correlation is sometimes subjective and most of the time multi-collinearity is detected using an indicator called Variance Inflation Factor (VIF) which measures and quantifies to what extent variance is inflated. VIFs are calculated by the regression analysis software, and a VIF less than 5 is an acceptable level of multi-collinearity (Daoud, 2017). The collinearity tests for the variables are included (see Appendix 5).

In the analysis, a number of variables were assumed to influence the farmers' perceptions of climate change, and after subjecting them to the test for collinearity, they were dropped because they had a strong collinearity. These variables included the number of livestock types owned per farmer, the number of livestock types sold, the number of livestock lost to drought, age range, education level range cohorts, farmers' knowledge of problems associated with climate change, and land tenure. Furthermore, some variables demonstrated collinearity close to the recommended cut-off point, and these were transformed or re-coded into reduced ranges; for example, "Other farm activities the farmers were engaged in" was re-categorised into the main crops the farmers grew (such as grain crops, vegetables, sugarcane, cotton, mixed or none). There was no "None"; hence, they were re-coded into two groups, namely: mono-crops or mixed crops. The other variables that were re-coded included the constituencies: from 10 to 3 based on rainfall records. The occupation of the farmers was re-coded from four to two cohorts, namely: "Farmer" and "Other", while household size was re-coded from five to two cohorts (< 10 persons and ≥10 persons per household).

5.7.1 The data used for modelling

This study used data collected from 278 households from the Lowveld of Eswatini as well as meteorological records from the Eswatini Meteorological Department for the modelling. The dependant variables were either the perception or adaptation strategy choices used by the households. The choice of explanatory variables was based on literature, and the data collected from the respondents. The predictor variables examined by the study consisted of both socio-economic and demographic variables. Table 5.16 summarizes the Predictor variables used for the Multinomial Logistic (MNL) regression.

Table 5-16: Description of explanatory variables

Predictor / Explanatory variable	Mean	Std. Deviation	Expected sign	Description
Age	0.78	0.41	±	Dummy, value of 1 if ≥40yrs and 0 otherwise
Constituency NCS	1.81	0.77	±	Dummy, value of 1 if north and 2 if central and 0 otherwise
Employment status	1.80	0.40	±	Dummy, value of 1 if employed and 0 otherwise
Gender	1.22	0.41	±	Dummy, value of 1 if male and 0 otherwise
Occupation (	1.31	0.46	+	Dummy, value of 1 if its farming and 0 otherwise
Marital status	0.63	0.48	+	Dummy, value of 1 if married and 0 otherwise
Household Size	0.74	0.44	+	Dummy, value of 1 if ≥10 persons and 0 otherwise
Crops Farmed	0.41	0.49	±	Dummy, value of 1 if multi-cropping and 0 otherwise
Climate change knowledge	0.89	0.31	+	Dummy, value of 1 if have knowledge and 0 otherwise
Access to Climate Information	0.78	0.41	+	Dummy, value of 1 if have access and 0 otherwise
Farm Manager	1.42	0.69		Dummy, value of 1 if head of household and 2 if family member and 0 otherwise
Owns large Livestock Units/cows	0.91	0.28	±	Dummy, value of 1 if owns cattle and 0 otherwise
Owns small Livestock goats or sheep	0.79	0.41	±	Dummy, value of 1 if owns goats or sheep and 0 otherwise
Lost livestock to drought	0.72	0.45	+	Dummy, value of 1 if lost livestock and 0 otherwise
Education	7.41	4.82	+	Continuous
Years keeping livestock	19.82	9.00	+	Continuous
Expenses livestock farming	19,473.26	58,078.42	+	Continuous
Income livestock farming	44,953.96	97,738.15	+	Continuous

5.7.2 Modelled farmers perceptions on climate

To emphasise the influence of the predictor variables on the perceived changes in climate using five climatic variables namely; temperature, rainfall, wind, drought frequency and rainfall season and the perceived causes of climate change, five separate MNL models were developed and ran. The predictor variables in these perception models were the same for all the models. In the model, climate change perception variables (temperature, rainfall, rain season, wind, and drought frequency) were the dependant variables with the other variables being the independent variables. The MNL results revealed that there are several variables that are significant predictors of the farmers' perception of a climate variable.

5.7.2.1 Predictors of farmers' perceptions of changes in temperature

Table 5.17 shows the MNL results of how farmers perceive variation temperatures a result of changes in climate. The MNL analysis about the perceived changes in temperature showed that no explanatory variable was a significant predictor of the farmers' perception of temperature. Furthermore, the likelihood of ratio statistics, as indicated by Chi-square = 26.496, was found to be insignificant at $p= .328$, suggesting the model's weak explanatory power. From the results, the reference level "No change" in temperature was compared with the estimated coefficients of the other two categories "Increased or Decreased" of perceived changes in the variable. For the perception of temperature change, the two categories of perceived changes in temperature exhibit different likelihoods to the diverse explanatory variables utilised in the analysis. However, these are all insignificant, and therefore, will not be discussed.

The perceptions are similar to the findings of Kichamu *et al.* (2018) who found that farmers perceived an increase in temperatures as part of climate change. Similarly, Mulenga *et al*. (2017) noted that Zambia has grown warmer. This is, however, different because these results are insignificant mainly because all the farmers 99.3% (276) stated that temperatures had increased.

Table 5-17: Predictors of farmers' perception of temperature

Temperature Perception	Increase			Decrease		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	265.694	.995		-24.524	1.000	
Education	-12.474	.993	0.000	-23.359	.992	0.000
Years keeping livestock	2.938	.994	18.872	13.427	.992	6.78E+05
Income livestock farming	0.000	1.000	1.000	0.000	1.000	1.000
Age (0=18-39yrs; 1 = >40yrs)	70.941	.998	6.45E+30	283.008	.995	8.11E+122
Household Size(0=<10; 1= >10persons)	-155.664	.993	0.000	-132.975	.995	0.000
Crops Farmed (0=Monocropping; 1= Multicropping)	-111.207	.994	0.000	-116.770	.998	0.000
Farm Manager (0= other]	76.391		1.50E+33	67.162		1.472E+29
Farm Manager(1= Head Household]	115.126	.994	9.96E+49	72.851	.997	4.351E+31
Farm Manager(2= Family Members)	0.000			0.000		
Constituency NCS (1. North]	-28.774	.999	0.000	-98.262	.998	0.000
Constituency NCS (2= central)	78.494	.998	1.23E+34	50.814	.999	1.17E+22
Constituency NCS (3= South)	0.000			0.000		
Gender (0= Female :1 = Male)	24.353	.999	3.77E+10	8.202	1.000	3646.516
Marital status (0 = Other; 1 = Married]	-22.869	.999	0.000	-40.007	1.000	0.000
Observations used= 278 ; LR chi-square=26.496 ; p= .328 ; Psuedo R^2 (Nagelkerke)= 1.000 ; Classification= 100%						
Reference Level = No Change; Significance: ***= p<.001; **= p <.05; *= p<0.1						

5.7.2.2 Predictors of farmers' perceptions of rainfall

Presented in Table 5.18 are the MNL regression results of how farmers perceive variation of rainfall. From the analysis, two explanatory variables (age and constituency) are significantly (p<.001) associated with their perception of an increase in rainfall amount. Furthermore, the likelihood ratio statistics, as indicated by Chi-square = 56.881, was highly significant at p=.000 suggesting the model's strong explanatory power.

With regard to age, young farmers (18 - 39years) are 8.466 times more likely to perceive 'an increase in rainfall' as opposed to perceiving a 'no change in rainfall'. This, in turn, means that older farmers (>40 years) are most likely to perceive a 'no change in the rainfall' than 'an increase in the rainfall'. Furthermore, farmers whose constituency (or area of residence) is in the central part of the Lowveld are 6.760 times most likely to perceive 'an increase in rainfall' as opposed to a 'no change in rainfall'.

Table 5-18: Predictors of farmers' perception of rainfall

Perception Rainfall Amount	Increase			Decrease		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	.105	.969		2.998	.103	
Education	-.139	.311	0.871	-.145	.161	0.865
Years keeping livestock	.059	.476	1.061	-.077	.153	0.926
Income livestock farming	.000	.112	1.000	.000	.279	1.000
Age (0=18-39yrs; 1 = $\geq$40yrs)	**2.136**	**.000*** **	**8.466**	1.977		7.221
Household Size(0=<10; 1= $\geq$10persons)	-.723	.607	0.485	.762	.389	2.143
Crops Farmed (0=Monocroping; 1= Multicroping)	-.415	.724	0.661	1.055	.185	2.873
Farm Manager (0= other]	-.419		0.657	19.673	.998	3.50E+08
Farm Manager(1= Head Household, 2 = family member]	-.932	.441	0.394	.496	.528	1.642
Constituency NCS (1. North, 3 south)	-1.008	.404	0.365	1.120	.156	3.065
Constituency NCS (2= central)	**1.911**	**.000*** **	**6.760**	2.136		8.466
Gender (0= Female :1 = Male)	.711	.634	2.037	-.344	.721	0.709
Marital status (0 = Other; 1 = Married	.173	.894	1.189	.562	.538	1.754
Observations used=278; LR chi-square= 56.881; p=.000; Psuedo R^2 (Nagelkerke)= .391; Classification= 93.2%						
Reference Level = No Change; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.1						

5.7.2.3 *Predictors of farmers' perceptions of the rainfall season*

The MNL results of how the livestock farmers perceive variation the rainfall season as result of changes in climate are displayed in Table 5.19. They illustrate that six explanatory variables (education, number of years farming livestock, income from livestock farming, age, types of crops farmed, who the farm manager is, and farmers constituency or area of residence) are significant predictors of the farmers' perception of the rainfall season, while the household size, gender, and marital status were not significant. Furthermore, the likelihood ratio statistics, as indicated by Chi-square = 95.098, was highly significant at p=.000 suggesting the model's strong explanatory power. These results reference level "no change" in rainfall season was compared with the estimated coefficients of the other two categories "increased or decreased" of perceived changes in the rainfall season. For the perception of change, the two categories of perceived changes in the rainfall season have different likelihoods to the different explanatory variables utilised for analysis.

The perceptions of the perceived changes in the rainfall season as increasing are significantly predicted by education ($p < 0.1$), age ($p < 0.05$), and farmers constituency or area of residence being in the northern part of the Lowveld ($p < 0.001$). With regards to education, a unit increase in years of schooling reduces the odds of perceiving ‘an increase in the rainfall season’ by 0.858 times than perceiving a ‘no change in the rainfall season’. In other words, it is highly possible that educated farmers would perceive a ‘no change in rainfall season’ than to perceive otherwise. While, on the other hand, young farmers (aged between 18 – 39 years) are 10.430 times more likely to perceive ‘an increase in rainfall season’ as opposed to perceiving the opposite. Simply put, older farmers (≥40 years) are more likely than young farmers to perceive a ‘no change in the rainfall season’ than to perceive ‘an increase in the rainfall season’. Moreover, farmers whose constituency (or area of residence) is in the northern part of the Lowveld are 0.121 times less likely to perceive ‘an increase in rainfall season’ as opposed to a ‘no change in rainfall season’.

The farmers perception of a decrease (or shortening) of the rainfall season was significantly predicted by the number of years they have kept livestock ($p < 0.05$); the farmers age ($p < 0.1$); the types of crops they farmed ($p < 0.1$); who managed the livestock farm ($p < 0.05$); and famers constituency or area of residence ($p < 0.05$). With respect to the number of years the farmers have farmed (kept) livestock, a unit increase in years of farming livestock increases the likelihood of perceiving a decrease in the rainfall season by 1.046 times, than perceiving a no change in the rainfall season. In other words, newer (less years farming) livestock farmers are most likely to perceive a ‘no change in rainfall season’ than to perceive a ‘decrease in rainfall season’; while young farmers (aged between 18 – 39 years) are 2.594 times more likely to perceive a ‘decrease in rainfall season’ instead of perceiving a ‘no change in rainfall season’. This a clear indication that older farmers (≥40 years) are more likely than younger farmers to perceive a ‘no change in the rainfall season’ than to perceive a ‘decrease in the rainfall season’. There was also an association between the types of crops they farmed and the farmers’ perception whereby, livestock farmers who practised mono-cropping are 1.870 times more likely to perceive a ‘decrease in rainfall season’ instead of perceiving a ‘no change in rainfall season’; or alternatively farmers who practiced multi-cropping are highly likely to perceive ‘no change in the rainfall season’ as opposed to perceiving a ‘decrease in the rainfall season’. While the perception to a decrease in the rainfall season also depends on who the livestock farm manager is. For instance, where the livestock manager is not the household head or family member, but other individuals are 10.718 times more likely to perceive a ‘decrease in rainfall season’ instead of perceiving a ‘no change in rainfall season’. Whereas where the farm manager is the head of household the likelihood of perception of a ‘decrease in rainfall season’ instead of perceiving a ‘no change in rainfall season’ is 2.578 times more likely. From this association, it can be deduced that when the farm manager is a family member, they are most likely to perceive ‘no change in the rainfall season’ as opposed to perceiving a ‘decrease in the rainfall season. Moreover, farmers whose constituency (or area of residence) is in the central part of the Lowveld of Eswatini are 6.260 times more likely to perceive a 'decrease in rainfall season' instead of a 'no change in rainfall season'.

Table 5-19: Predictors of farmers' perception of the rainfall season

Rain Season Perception	Increase			Decrease		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	-.367	.818		-.807	.318	
Education	**-.153**	**.069***	**0.858**	-.001	.982	0.999
Years keeping livestock	.079	.103	1.082	**.045**	***.037****	**1.046**
Income livestock farming	.000	.555	1.000	.000	.423	1.000
Age (0=18-39yrs; 1 = ≥40yrs)	**2.345**	**.031****	**10.430**	**.953**	**.088***	**2.594**
Household Size(0=<10; 1= ≥10persons)	-1.199	.177	0.302	.085	.838	1.089
Crops Farmed (0=Mono-cropping; 1= Multi-cropping)	-.680	.307	0.506	**.626**	**.078***	**1.870**
Farm Manager (0= other]	-18.063		0.000	**2.372**	**.026****	**10.718**
Farm Manager(1= Head Household]	-.490	.546	0.613	**.947**	**.017****	**2.578**
Constituency NCS (1. North]	**-2.116**	**.011****	**0.121**	-.687	.121	0.503
Constituency NCS (2= central)	-.603	.536	0.547	**1.834**	**.001****	**6.260**
Constituency NCS (3= South)	0			0		
Gender (0= Female :1 = Male	-.301	.711	0.740	-.277	.520	0.758
Marital status (0 = Other; 1 = Married]	-.789	.311	0.454	.180	.634	1.197
Observations used= 278 ; LR chi-square=95.098; p=.000; Psuedo R^2 (Nagelkerke)= .377; Classification=76.3%						
Reference Level = No Change; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.1						

5.7.2.4 *Predictors of farmers perceptions of drought frequency*

The MNL regression results of how farmers perceive drought frequency are presented in Table 5.20. From this analysis of results, one explanatory variable (constituency) was significantly ($p < 0.001$) associated with farmers' perception of an increase and decrease in drought frequency. Livestock farmers whose constituency (or area of residence) is in the northern part of the Lowveld Eswatini are 0.142 times less likely to perceive 'an increase in rainfall season' as opposed to a 'no change in rainfall season', while those farmers whose constituency (or area of residence) is in the central part of the Lowveld are 0.155 times less likely to perceive an increase in rainfall season as opposed to a no change in rainfall season. Whereas, farmers whose constituency (or area of residence) is in the northern part of the Lowveld are 0.125 times less likely to perceive a 'decrease in rainfall season' as opposed to a 'no change in rainfall season'.

Table 5-20: Determinants of farmers' perception to drought frequency

Drought Frequency Perception	Increase			Decrease		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	20.884	.000***		18.804	.000***	
Education	.033	.684	1.033	.103	.326	1.109
Years keeping livestock	.031	.411	1.032	.027	.585	1.028
Income livestock farming	.000	.120	1.000	.000	.603	1.000
Age (0=18-39yrs; 1 = >40yrs)	.623	.519	1.864	1.512	.200	4.534
Household Size(0=<10; 1= >10persons)	1.617	.155	5.036	-17.440	.997	0.000
Crops Farmed (0=Monocroping; 1= Multicroping)	.813	.220	2.254	.972	.264	2.643
Farm Manager (0= other]	21.914	.998	3.29E+09	20.643	.998	9.23E+08
Farm Manager(1= Head Household]	-.989	.172	0.372	-1.033	.251	0.356
Farm Manager(2= Family Members)	0			0		
Constituency NCS (1. North]	***-1.951***	***.000****	0.142	**-2.078**	**.000*****	0.125
Constituency NCS (2= central)	***-1.862***	***.000****	0.155	-20.679		0.000
Constituency NCS (3= South)	0			0		
Gender (0= Female :1 = Male	.323	.641	1.381	.388	.675	1.475
Marital status (0 = Other; 1 = Married]	-.596	.377	0.551	-1.199	.188	0.301
Observations used= 278 ; LR chi-square=46.565; p=.004; Psuedo R^2 (Nagelkerke)=.274; Classification=88.8%						
Reference Level = No Change; Significance: ***= p<.001; **= p <.05; *= p<0.1						

5.7.2.5 Predictors of farmers perceptions of wind

The MNL results of how farmers perceive wind, as an indicator of climate change are presented in Table 5.21. Perceptions of the perceived changes of wind as increasing are influenced significantly by age ($p < 0.05$); household size($p < 0.1$); who the farm manager is, "other persons, or household head" ($p < 0.01$); and farmers' constituency or area of residence being in the northern part of the Lowveld ($p < 0.001$).With respect to age, young farmers (aged between 18 – 39 years) are 0.254 times less likely to perceive 'an increase in wind' as opposed to perceiving a 'no change in wind'. With regard to household size, farmers whose household consisted of more than 10 persons are 2.512 times most likely to perceive 'an increase in wind' instead of perceiving a 'no change in wind'; clearly indicating that smaller household sizes (<10 persons) are more likely than larger households to perceive a 'no change in the wind' than to perceive 'an increase in wind'. Where the farm manager is not the head of household or family member, the likelihood of perception of 'an increase in wind' as opposed to perceiving a 'no change in wind' decreases by 0.11 times, but the likelihood of a decreasing perception of wind by a farm manager who is head of household decreases by 0.091 times. Moreover, farmers whose constituency (or area of residence) is in the northern part of the Lowveld are 0.078 times less likely to perceive 'an increase in wind' as opposed to a 'no change in wind'.

The farmers' perception of a decrease of wind was significantly influenced by, who the farm manager is: either "other persons ($p < 0.05$) or the household head" ($p < 0.01$); the farmers' constituency or area of residence either "north or central" ($p < 0.1$); and the marital status of the farmers ($p < 0.05$). The perception to a decrease in wind was found to depend on who the livestock farm manager is. Where the manager is not the household head or family member but other individuals, the likelihood of them perceiving a 'decrease in wind' as opposed to perceiving a 'no change in wind' decreases 0.140 times. Whereas, where the farm manager is the head of household the likelihood of perception of a 'decrease in wind' as opposed to perceiving a 'no change in wind' is 0.113 times less likely. From this association, it can be deduced that when the farm manager is a family member, they are most likely to perceive a 'no change in the wind' as opposed to perceiving a 'decrease in the wind'.

With regard to the famer's constituency or area of residence, it was found that farmers from the north and central part of the Lowveld of Eswatini were about 0.2 times less likely to perceive a 'decreased in winds' than perceiving a 'no change in winds'. In other words, farmers from the southern part are most likely to perceive a 'no change in winds' than a 'decrease in winds'; while farmers who were not married are 2.959 times more likely to perceive a 'decrease in wind' instead of perceiving a 'no change in wind', a clear indication that married farmers are more likely than unmarried farmers to perceive a 'no change in the wind' than to perceive a 'decrease in wind'.

Table 5-21: Predictors of farmers' perception of wind

Wind Perception	Increase			Decrease		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	4.349	.000***		.991	.377	
Education	.063	.192	1.065	.099	.123	1.104
Years keeping livestock	-.020	.433	0.980	.003	.917	1.003
Income livestock farming	.000	.338	1.000	.000	.240	1.000
Age (0=18-39yrs; 1 = ≥40yrs)	**-1.372**	**.019****	**0.254**	.265	.711	1.304
Household Size(0=<10; 1= ≥10persons)	**.921**	**.061***	**2.512**	-.353	.612	0.702
Crops Farmed (0=Monocroping; 1= Multicroping)	.201	.617	1.223	-.033	.949	0.968
Farm Manager (0= other]	**-2.205**	**.001*****	**0.110**	**-1.967**	**.017****	**0.140**
Farm Manager(1= Head Household]	**-2.398**	**.000*****	**0.091**	**-2.179**	**.000*****	**0.113**
Farm Manager(2= Family Members)	0			0		
Constituency NCS (1. North]	**-2.555**	**.000*****	**0.078**	**-1.527**	**.054***	**0.217**
Constituency NCS (2= central)	-.667	.299	0.513	**-1.570**	**.075***	**0.208**
Constituency NCS (3= South)	0			0		
Gender (0= Female :1 = Male)	-.612	.251	0.543	-.476	.456	0.621
Marital status (0 = Other; 1 = Married)	.223	.612	1.250	**1.085**	**.042****	**2.959**
Observations used=278; LR chi-square=111.463; p=.000; Psuedo R^2 (Nagelkerke)=.409; Classification=74.8%						
Reference Level = No Change; Significance: ***= p<.001; **= p <.05; *= p<0.1						

5.7.3 Predictors of climate change impact on household level

To highlight the effects of the explanatory variables on the perceived impacts of climate change on the farmers' household, a MNL regression model was developed and ran. A multi-collinearity test was conducted, prior to running of the model, on all independent variables, and a number of variables were assumed to influence farmers' perceptions. After subjecting them to the test for collinearity, they were dropped because they had a strong collinearity, after that the test was run.

The results of the MNL regression on how farmers perceive the impact of climate change on their household are outlined in Table 5.22. The analysis of the perceived impact on the household level indicated that nine explanatory variables were significantly predictors of the farmers' perception of a 'negative impact' on the household, and one explanatory variable were significantly predictor of the farmers' perception of a 'positive impact' on the household. Furthermore, the likelihood ratio statistics, as indicated by Chi-square = 119.915, were significant at $p= .000$, suggesting the model's strong explanatory power.

The variables associated with a negative perception are: Education ($p < 0.05$); Farmers' constituency or area of residence ($p < 0.1$); Is the farmer employed ($p < 0.05$); Gender ($p < 0.05$); occupation($p < 0.1$);, Who the farm manager is ($p < 0.05$); Do not own cattle - large livestock units ($p < 0.1$); Do not own goats and sheep -small livestock units ($p < 0.05$); Did not lose livestock to drought ($p < 0.05$). Whereas, the variable associated with a positive impact of climate change on the household is the farmers' employment status ($p < 0.1$).

With regards to education, a unit increase in years of schooling reduces the likelihood of perceiving a negative impact of climate change on the household by 0.864 times than perceiving a 'no impact' of climate change on the household. In short, educated farmers are most likely to perceive a 'no impact' of climate change on the household than to perceive 'negative impacts' of climate change on the household. While farmers whose constituency (or area of residence) is in the northern part of the Lowveld of Eswatini are 4.580 times most likely to perceive 'negative impacts' of climate change on the household as opposed to perceiving 'no impact' of climate change on the household. Whereas farmers whose constituency (or place of residence) is in the central part of the Lowveld are 0.387 times less likely to perceive' negative impacts' of climate change on the household as opposed to perceiving 'no impact' of climate change on the household. The farmers' employment status indicated that employed farmers are 0.154 times less likely to perceive 'negative impacts' of climate change on the household as opposed to 'no impact' of climate change on the household; while male farmers (gender) are 2.965 times most likely to perceive ‘negative impacts’ of climate change on the household as opposed to perceiving ‘no impact’ of climate change on the household. In other words, female farmers are most likely to perceive ‘no impacts’ of climate change on the household than males. Farmers whose occupation is farming are 0.326 times less likely to perceive ‘negative impacts’ of climate change on the household as opposed to perceiving ‘no impact’ of climate change on the household; meaning, livestock farmers whose main occupation is not farming are most likely to perceive ‘no impacts’ of climate change on the household than farmers whose main occupation is farming. Whereas where the farm manager is not the head of household or a family member but someone else, the likelihood of a ‘negative impact’ perception on the household as opposed to ‘no impacts’ is 0.207 times less likely. From this association, it can be deduced that when the farm manager is a family member, they are more likely to perceive ‘no impacts’ of climate change on the household than farm managers who are not family members.

Livestock farmers who own *cattle (large livestock unit)* are 0.256 times less likely to perceive ‘negative impacts’ of climate change on the household as opposed to perceiving ‘no impact’ of climate change on the household, than those who own livestock. Similarly, farmers who own *goats and sheep* (small livestock units) are 0.332 times less likely to perceive ‘negative impacts’ of climate change on the household as opposed to perceiving ‘no impact’ of climate change on the household than those who own livestock. In other words, livestock farmers (mainly cattle farmers) are most likely to perceive ‘negative impacts’ of climate change on the household than those who do not own cattle, goats or sheep but other types of livestock. Lastly, livestock farmers who have not lost livestock to drought are 0.334 times less likely to perceive negative impacts of climate change on the household as opposed to perceiving ‘no impact’ of climate change on the household than those who lost livestock to drought. In other words, livestock farmers who lost livestock to drought are most likely to perceive ‘negative impacts’ of climate change on the household than those who did not.

With regard to perceiving a positive impact of climate change on the household only the farmers’ employment status indicated that employed farmers are marginally (0.004 times) less likely to perceive ‘positive impacts’ of climate change on the household as opposed to perceiving ‘no impacts’ of climate change on the household.

Table 5-22: Predictors of climate change impacts on the household

Perception of Climate change Impact on the household	Negatively			Positively		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	**6.566**	**.000*** **		-7.653	.382	
Education	**-.146**	**.024** **	**.864**	.421	.310	1.523
Years keeping livestock	-.049	.132	.952	.198	.217	1.219
Expenses livestock farming	.000	.116	1.000	-.001	.198	.999
Income livestock farming	.000	.392	1.000	.000	.559	1.000
Constituency NCS (1. North]	**1.522**	**.064***	**4.580**	-22.894	.997	1.141E-10
Constituency NCS (2= central)	**-.950**	**.094***	**.387**	-2.344	.314	.096
Constituency NCS (3= South)	0			0		
Employed (0=No: 1=Yes	**-1.871**	**.005** **	**.154**	**-5.514**	**.096***	**.004**
Gender (0= Female :1 = Male	**1.087**	**.042** **	**2.965**	7.253	.148	1412.666
Occupation (0= Other: 1.=Farming)	**-1.121**	**.073***	**.326**	-.702	.835	.495
Marital status (0 = Other; 1 = Married)	-.574	.262	.563	5.856	.198	349.243
Household Size (0=<10; 1= ≥10persons)	-.170	.755	.844	-21.208	.997	6.161E-10
Crops Farmed (0=Monocroping; 1= Multicroping)	-.178	.718	.837	-1.507	.437	.221
Climate change knowledge (0 =No: 1=Yes)	1.424	.228	4.153	-6.576	.999	.001
Access to Climate Information(0 =No: 1=Yes)	-.730	.222	.482	-17.573	.998	2.334E-08
Farm Manager (0= other,1]	**-1.576**	**.020** **	**.207**	.098	.972	1.103
Farm Manager(1= Head Household]	-.816	.123	.442	1.452	.532	4.271
Farm Manager(2= Family Members)	0^b			0^b		
Owns large Livestock Units(0 =No: 1=Yes)	**-1.363**	**.056***	**.256**	-20.742		9.819E-10
Owns small Livestock Units (0 =No: 1=Yes)	**-1.102**	**.030** **	**.332**	-23.234	.997	8.123E-11
Lost livestock to drought (0 =No: 1=Yes)	**-1.097**	**.034** **	**.334**	-24.330	.997	2.713E-11
Observations used=278; LR chi-square=119.915; p=.000; Psuedo R^2 (Nagelkerke)=.550; Classification=88.1%						
Reference Level = No Impact; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.2						

5.7.4 Perception of climate change impact on livestock farming

This section presents the empirical results of the MNL perception model on the perceived impact of climate change on livestock farming. The MNL using all the possible independent variables, as listed in the in Appendix 5 collinearity, failed to produce satisfactory results in terms of the significance level of likelihood ratios and of the parameters estimates. The model was, thus, restructured re-run.

The MNL regression analysis regarding farmers' perceptions as to the impacts of climate change on livestock farming indicated (see Table. 5.23) a significant association with six variables namely: education ($p < 0.1$), gender ($p < 0.05$), household size ($p < 0.1$), access to climate information ($p < 0.1$), farm manager is head of house ($p < 0.1$), and do not own cattle - large livestock units ($p < 0.05$). These variables were significantly predictors of a negative impact of climate change on livestock farming. The likelihood ratio statistics, as indicated by the Chi-square 67.481, were highly significant at a level of $p<0.001$, suggesting the model's strong explanatory power. It should be noted that the estimated likelihoods are compared with the reference level "No Impact" of climate change on livestock farming

With regards to education, a unit increase in years of schooling increases the likelihood of perceiving a ‘negative impact’ of climate change on the livestock farming by 1.087times than perceiving a ‘no impact’ of climate change on livestock farming. That is to say, less educated farmers are most likely to perceive a ‘no impact’ of climate change on livestock farming than to perceive ‘negative impacts’ of climate change on livestock farming when compared with educated farmers. Moreover, males are 3.557 times more likely to perceive ‘negative impacts’ of climate change on livestock farming instead of ‘no impacts’ of climate change on livestock farming. While, households with more than 10 persons are 3.610 times most likely to perceive that climate change impacts on livestock farming than it having ‘no impacts’ on livestock farming. Whereas, farmers with no access to climate information are 3.168 times most likely to perceive that climate change impacts on livestock farming rather than it having ‘no impacts’. Similarly, where the farm manager is head of a household their perception of climate change as having a negative impact on livestock farming is 2.335 times more likely than perceiving it having ‘no impact’ on livestock farming; while the perception of climate change as having a negative impact on livestock farming for farmers who do not own cattle (large livestock units) is 0.131 times less likely than perceiving it having ‘no impacts’ on livestock farming. In other words, livestock farmers who do not own cattle are more likely to perceive that climate change has ‘no impacts’ on livestock farming than those who own cattle.

Table 5-23: Determinants of climate change impact on livestock farming

Perception of Climate change Impact on Livestock farming	Negatively			Positively		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	-.589	.510		-.797	.609	
Education	**.083**	**.080***	**1.087**	-.073	.389	.929
Years keeping livestock	.021	.374	1.022	-.001	.974	.999
Income livestock farming	.000	.267	1.000	.000	.627	1.000
Constituency NCS (1. North]	-.819	.147	.441	-1.124	.261	.325
Constituency NCS (2= central)	.615	.304	1.849	-.037	.970	.963
Constituency NCS (3= South)	0^b			0^b		
Employed (0=No; 1=Yes]	-.803	.112	.448	-.180	.852	.835
Gender (0= Female :1 = Male	**1.269**	**.002****	**3.557**	.223	.753	1.250
Household Size (0=<10; 1= >10persons)	**1.284**	**.021***	**3.610**	.692	.422	1.998
Climate change knowledge (0 =No: 1=Yes)	.797	.351	2.219	-17.834		1.797E-08
Access to Climate Information(0 =No: 1=Yes)	**1.153**	**.053***	**3.168**	-.124	.918	.883
Farm Manager (0= other]	.056	.929	1.058	1.021	.304	2.777
Farm Manager(1= Head Household]	**.848**	**.079***	**2.335**	.559	.508	1.748
Farm Manager(2= Family Members)	0^b			0^b		
Owns large Livestock Units(0 =No: 1=Yes)	**-2.032**	**.002****	**.131**	-.625	.554	.535
Age (0=18-39yrs; 1 = >40yrs)	.827	.153	2.286	1.090	.271	2.974
Observations used=278; LR chi-square=67.481; p=.000; Psuedo R^2 (Nagelkerke)=.300; Classification=78.8%						
Reference Level = No Impact; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.2						

5.7.5 Summary on farmers perception

Before someone can adapt to climate change, they first have to perceive that the climate is changing. Therefore, the farmers' perceptions on climate change were sought using climatic indicators. The results indicated that, in general the farmers perceived that the following climatic variables were increasing temperature: hot days, drought severity, drought frequency, and winds; while the climatic variables, rainfall, rain days, the rain season, cold days and floods were perceived to decrease. There was variance in how farmers perceived temperature and rainfall across different locations, and the results indicated that there was a significant relationship between constituency (place of residence) and the farmers' perception to rainfall and temperature. These perceptions were also compared with climatic trend data, and the results for temperatures in the northern part of the Lowveld did not fully support the notion that temperatures were increasing with the exception of one month; however, temperatures were increasing in the southern part of the Lowveld. With regards to rainfall there was either a decline of rainfall in the northern part, though not significant, and a change in season in the southern part of the Lowveld of Eswatini.

The analysis indicated the majority of the farmers (89%) had knowledge on climate change. The farmers' knowledge was found to be significantly associated with age, education, household size, and farming income from livestock. The farmers also indicated that their major sources of climatic information were radio, television, family and neighbours, newspapers, and social networks.

The farmers indicated that they perceived climate change or variability had a negative impact on all their livelihood activities with the exception of family health where they were divided in opinion. Similarly, the majority of farmers (79%) indicated that their livestock farming was impacted by climate change.

The MNL Regression Model was utilised to determine which socio-demographic variables were the predictors of the farmers' perceptions. The results indicated that no variables significantly predicted the farmers' perception of temperature, while rainfall was significantly predicted by these variables: age and constituency. Whereas for the perceived changes in the rainfall season six explanatory variables predicted this perception, but one explanatory variable (constituency) predicted the farmers' perception of drought frequency. Lastly, changes of wind were associated with five variables, namely: age; household size; who is farm manager, the area of residence and marital status

The perceived impacts of climate change was also modelled using the MNL regression Model and the results indicated that nine explanatory variables predicted impacts on the household activities, while six variables predicted the perception that the livestock farming is negatively impacted by climate change and variability.

5.8 Evaluation of climate change adaptation

After understanding the farmers' perceptions of climate change, it was essential to understand their adaptation responses. Climate change adaptation involves describing both the proactive or reactive changes in natural and human systems in reaction to climate change, to minimize harm and enhance benefits (Deressa *et al*., 2008; Descheemaeker *et al*., 2016). Presented in this section are the different climate change adaptation actions used to minimise the impact of climate change on the farmers' households and livestock farming. Presented first are the approaches utilised by the farmers to adapt to climate change; second are the strategies used by the farmers to adapt to climate change; third are the predictors or determinants of adaptation, and last are the impediments to climate change adaptation for the livestock farmers in the Lowveld of Eswatini.

5.8.1 Approaches livestock farmers used for climate change adaption

The approaches the farmers used to adapt to climate change are divided into two: those used at the household level, and those used for livestock farming as presented below:

5.8.1.1 Approaches employed by farmers to adapt at the household level

According to Manyatsi *et al.* (2013), there are a number of strategies used by rural communities in Eswatini to adapt to climate change. Figure 5.29 presents the adaptation approaches (measures) that the farmers utilise for adapting to climate change impacts on their households. From Figure 5.28, it is evident that each adaptation approach was used differently. The main adaptation measures used, by percentage, were: water harvesting and storage; varied planting dates for crops; selling livestock; changing the crop varieties to drought tolerant ones; diversifying crops planted; and using agricultural extension services. Other less used adaptation measures included: seeking employment; the use of technology; relying on remittances; and doing nothing. These results are in part similar to results by other researchers such as Borokini *et al.* (2014) who indicated that some adaptation strategies used by farmers in Oyo State, Nigeria included planting new varieties, practicing mixed farming, and multiple cropping. While Vilane *et al.* (2015), in a study in Eswatini, highlighted that farmers used agricultural extension services to cope with climate change.

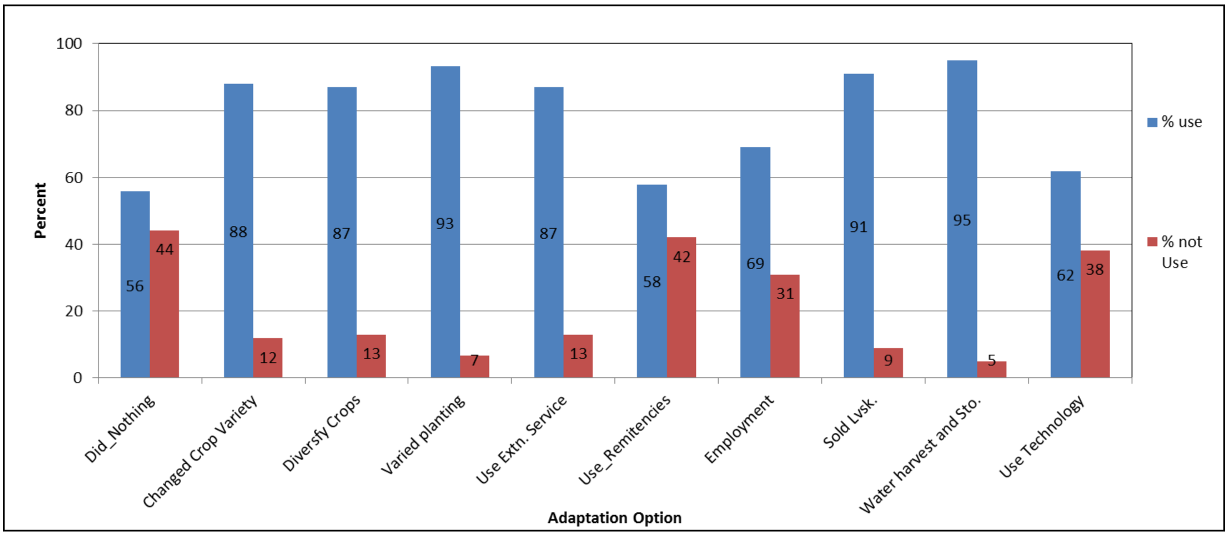


Figure 5-29: Household level adaptation measures used by farmers to adapt.

5.8.1.2 Strategies used for climate change adaptation at household level

To facilitate understanding of the different approaches used by farmers to adapt to climate change at the household level, these approaches were categorised into common adaptive strategies to climate change: technological, behavioural, and managerial strategies, in line with Silvestri *et al*. (2012) categorisation which combined the following approaches:

(i) Technological strategies combined: water harvesting and storage and technology use

(ii) Behavioural strategies combined: sold livestock, using agricultural extension services, relying on remittances and doing nothing

(iii) and managerial strategies combined: varied planting dates for crops, changing the crop varieties to drought tolerant ones and diversifying crops planted

The results of this categorisation and the farmers' responses realised that eight different strategies were employed by the farmers to adapt to climate change (see Figure 5.30). The three main adaptations strategies used by the farmers for adaptation, by percentage of usage, were: a strategy combining behavioural, managerial, and technological strategies which was used by about 61% of the respondents; followed by a strategy combining both behavioural and managerial strategies used by 10% of the respondents; and lastly a strategy combining managerial and technological practices used by 8% of the respondents. The other less used strategies mainly consisted of single approach strategies as well as a strategy combining both behavioural and technological strategies. Of interest was that, farmers who did not use any strategy for adaptation were 4%. This figure indicates that 96% of the farmers adapted their households and is far higher than the 61% who reported that they adapted to climate change.

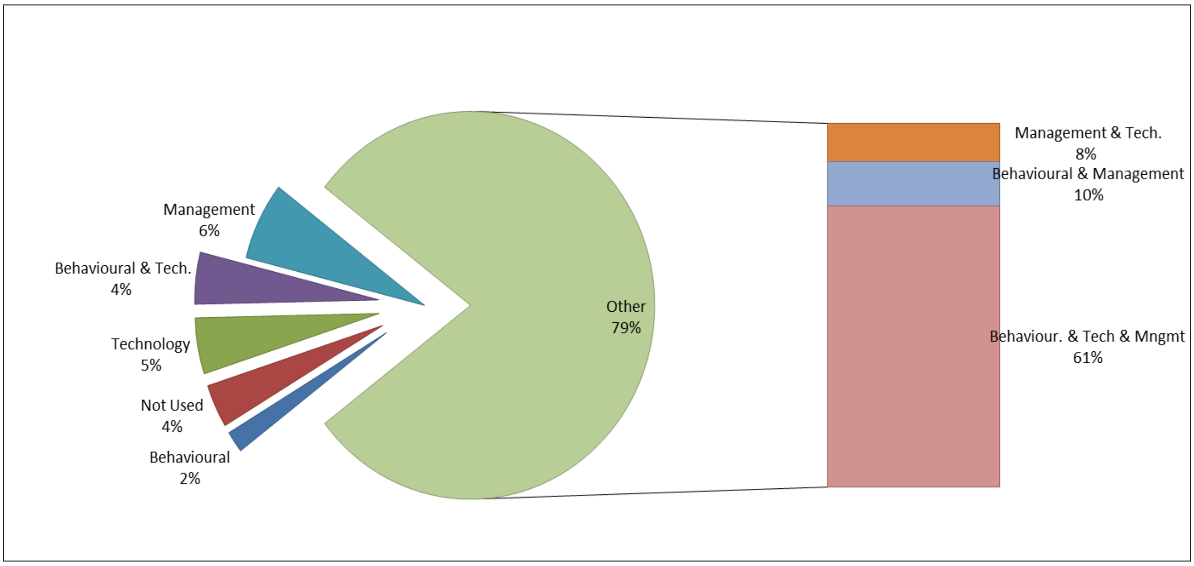


Figure 5-30: Household level climate change adaption strategies used by farmers

The strategies utilised by the respondents to adapt to climate change on their household activities were examined using spatial analysis and the outcome indicated that the strategies used varied with location (constituency), Figure 5.31.

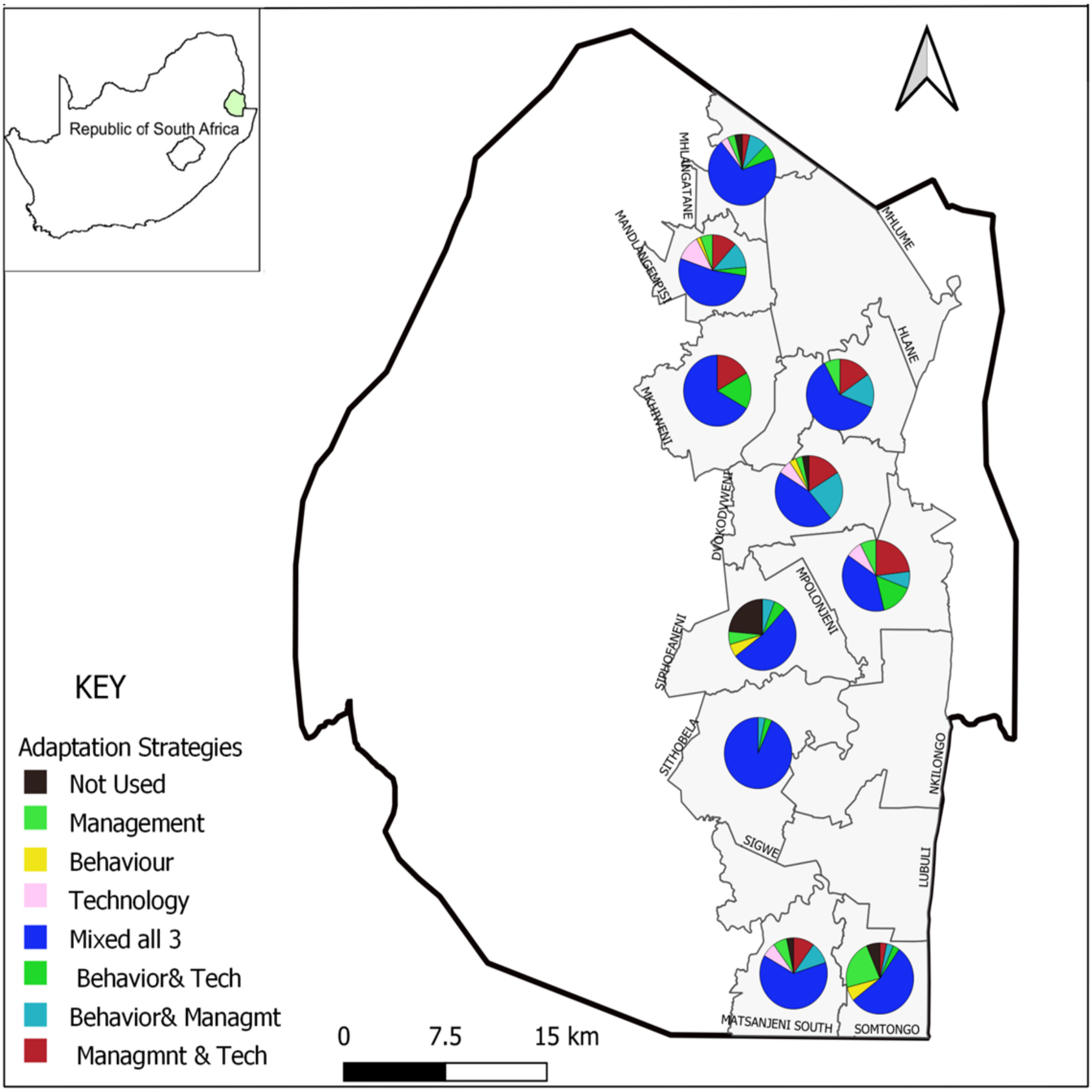


Figure 5-31: Spatial rendering of strategies used for adaptation at the household

5.8.1.3 *Approaches employed by the farmers to adapt livestock farming*

The adaptation approaches (measures) used by the livestock farmers in the Lowveld of Eswatini to adapt to climate change impacts on their livestock farming are illustrated in Figure 5.32. These results indicated that the farmers used 16 adaptation approaches and their level of usage varied.

The top five adaptations approaches used by the respondents for livestock farming are: the provision of medicines and pesticides; selling livestock; water harvesting and provision; seeking training; and engaging in mixed crop systems. The five least used adaptations approaches included: using insurance; borrowing funds; doing nothing; loaning out livestock; and relying on government provided food aid for livestock. Other adaptation practices used included: seeking for employment, restocking, use of forecasts, diversifying livestock, changing livestock breeds and supplementary feeding.

These results are comparable to those of a Kenyan study by Silvestri *et al*. (2012) and Comoé and Siegrist (2015) with regard to mixing crop and livestock production and destocking (selling livestock), but different with regard to diversifying, supplementing livestock feed, and changing animal breeds, where in Kenya, these were top adaptation choices. The results are also related to those of Kichamu *et al.* (2018) who found that during droughts, farmers in eastern Kenya cull animals; grow drought tolerant crop varieties; participate in non-farm income activities; vaccinated their livestock; and also engage in farming small livestock to reduce their vulnerability to climate risks.

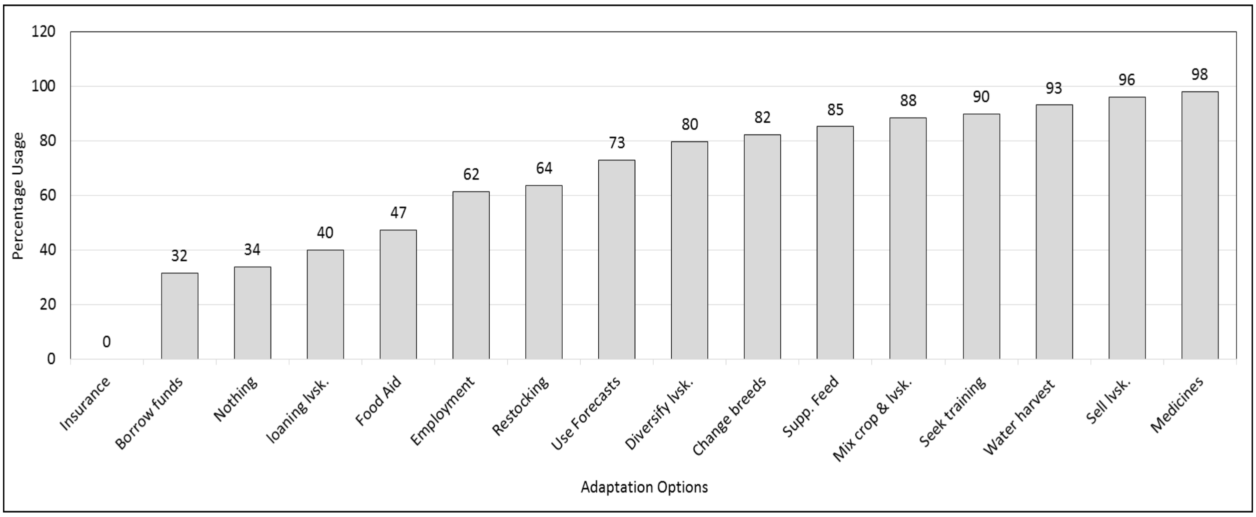


Figure 5-32: Adaptation measures used by farmers to adapt livestock farming

5.8.2 Strategies used for climate change adaptation of livestock farming

For ease of understanding the climate change adaptation approaches utilised by the farmers to adapt their livestock farming, these approaches were classified into three strategies, namely: technological, behavioural, and managerial similar to those proposed by Silvestri *et al*. (2012). The categorisation into strategies combined the following approaches:

(i) behavioural strategies combined: engaging in mixed crop systems, using insurance, them seeking employment borrowing funds, doing nothing, and relying on government provided food aid for livestock

(ii) managerial strategies combined: providing supplementary feeding, provision of medicines, dips and deworming licks and salts, selling livestock, loaning out livestock and restocking

(iii) and Technological strategies combined: water harvesting and provision, utilised of forecasts and early warning mechanism, seeking education and training diversifying livestock and changing livestock breeds

Following the categorisation, the farmers' responses produced eight different strategies to adapt to climate change (see Figure 5.33). From these, three dominantly used strategies were an adaptation strategy that combined managerial and technological strategies used by 41% of the farmers; followed by managerial strategies used by 15% of the farmers; and then adaptation strategies that combined behavioural, managerial and technological strategies used by 15% of the farmers. These top three strategies were used by 71% of the farmers. The other strategies used by the farmers included 'doing nothing' used by 13% of the farmers; followed by technological strategies used by 9% of the farmers to adapt; trailed adaptation strategies that combined behavioural and technological strategies used by 4% of the farmers was shadowed by adaptation strategies that used behavioural strategies used by 2% of the farmers; and lastly by adaptation strategies that combined behavioural and managerial strategies and used by 1% of the farmers. Of note is, some farmers (13%) 'did nothing' to adapt (did not adapt). This is far less than the 39 % who reported that they did not adapt, and this indicates that some farmers might not be aware that their activities are actual adaptations. Therefore, 26% of the livestock farmers are not aware that they are adapting to climate change through their activities for livestock farming.

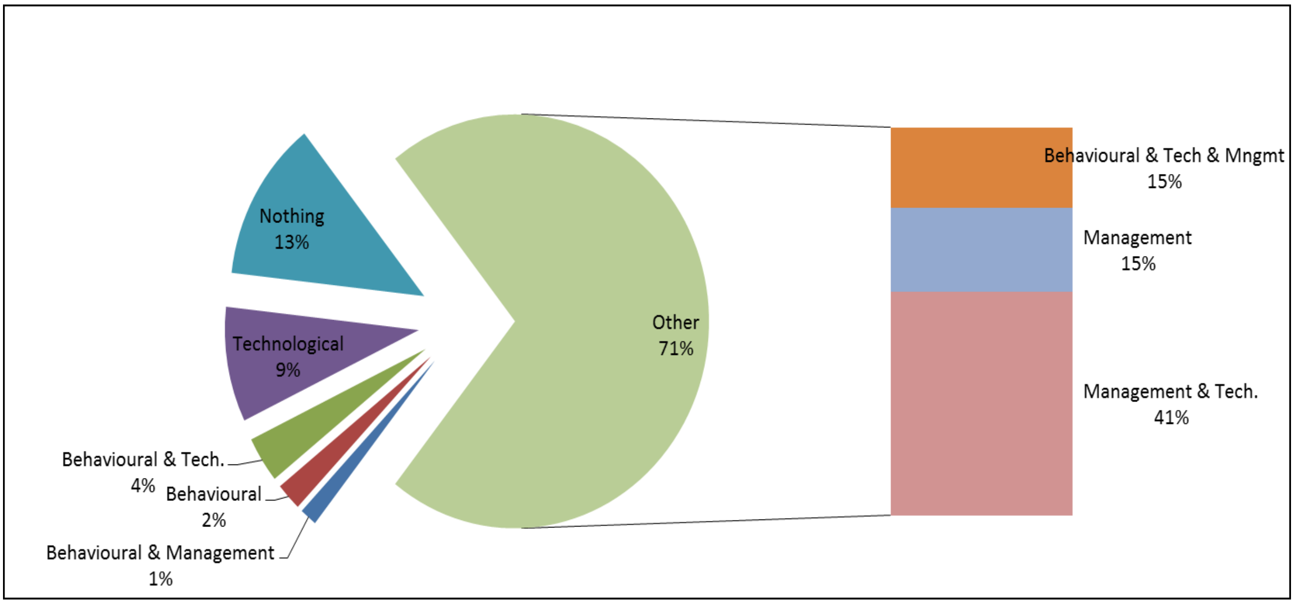


Figure 5-33: Livestock farming climate change adaptation strategies used by farmers to adapt

On further analysis, it was observed that the farmers' strategies varied with location, and the management and technology strategy did not dominate all constituencies. The spatial rendering of the strategies used by the farmers is outlined in Figure 5.34

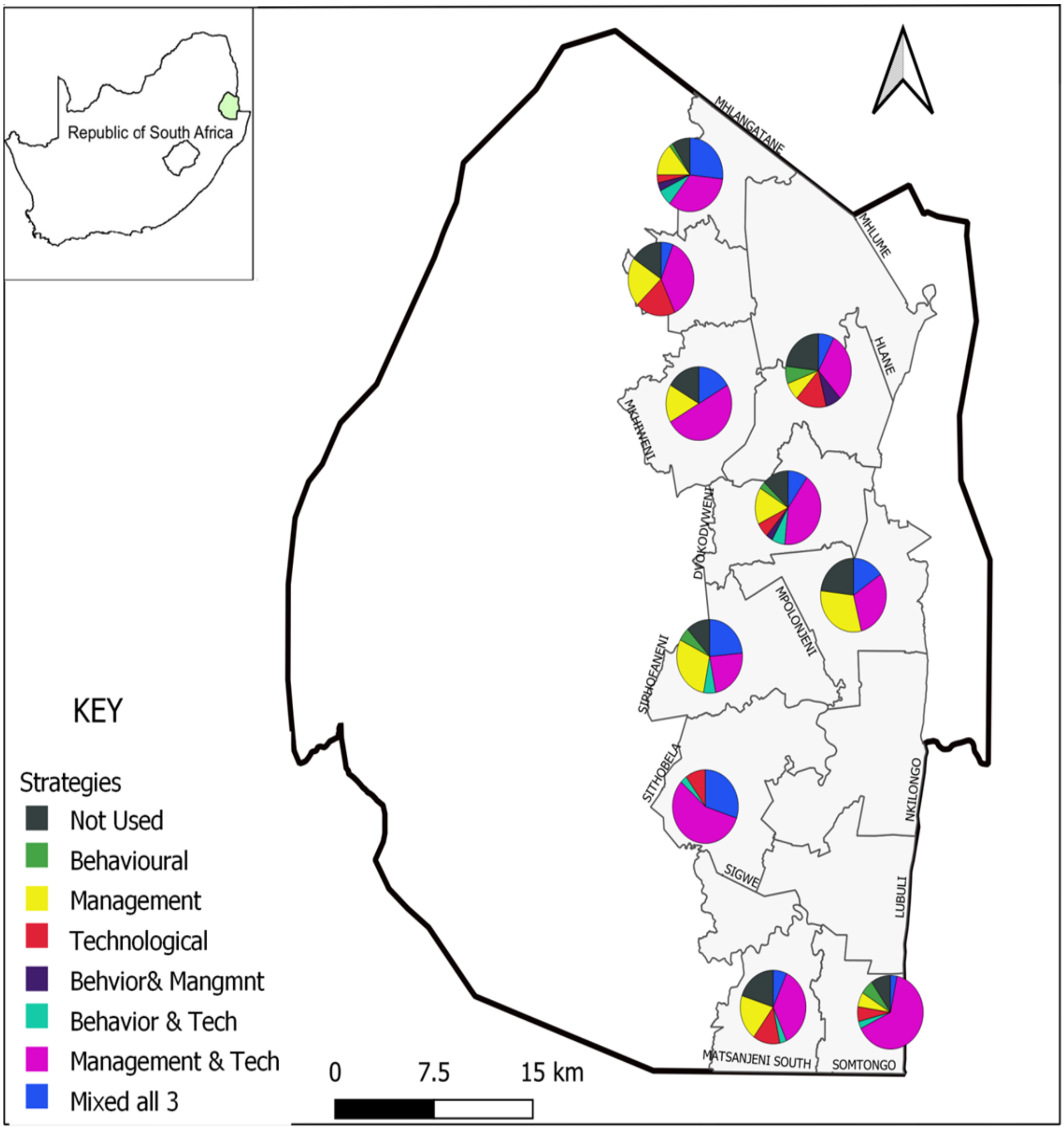


Figure 5-34: Spatial rendering of livestock farming adaptation strategies

5.8.3 Factors determining the adaptation strategy used by the farmers

Given that this study is looking into adaptation at the household or farm level, the MNL approach was used, and the reason being that it is widely used in adopting decisions to analyse the determinants (predictors) of the farmers' decisions to adapt to climate change (Hassan & Nhemachena, 2008). Furthermore, the study identified eight adaptation strategies utilised by the farmers to adapt to the impacts of climate change. These strategies were assigned values from 0 to 7. The strategy number 0, 1, 2, and 3 were stand-alone strategies, whereas strategy number 4 to 8 were a combination of strategies (mix of 1,2or 3). These strategies formed the dependant variable in the MNL regression analysis, while a number of socio-demographic variables formed the independent variables. All the variables were subjected to test for multi-collinearity using an indicator called Variance Inflation Factor (VIF) which is calculated by the regression software. As part of analysis, a VIF less than 5 is an acceptable level of multi-collinearity (Daoud, 2017). In this study, two MNL- regression analysis models were run to determine the determinants of climate change at both the household level and the livestock farming level. The results of this analysis are presented below:

5.8.3.1 Determinants of adaptation at the household level.

Given that there were eight strategies utilised by the farmers to adapt to climate change, the strategy ***"no adaptation"*** was used as the base strategy to determine how the variables influence each strategy These MNL results of the determinants of climate change adaptation at the household level indicated that 9 out of 13 explanatory variables significantly predicted the probability of adaptation. With the exception of the following variables: education, income livestock farming, employed, and climate change knowledge. The variables that are predictors (determinants) of adaptation included: years keeping livestock, constituency, gender, household size, types of crops farmed, access to climate information, who the farm manager is, cattle ownership, and goats or sheep ownership. Furthermore, the likelihood ratio statistics, as indicated by Chi-square = 229.491, was highly significant at *($p \leq .000$),* suggesting the model's strong explanatory power. Only those variables whose coefficients were statistically significant at ($p<0.1$) are discussed below.

5.8.3.1.1 Determinants of use of Individual Adaptation Strategies

Presented in Tables 5.24 first is the single adaptation strategies. The results show that, with reference to the adaptation strategy "Management options", four variables significantly predict the use of this strategy for adaptation. These variables are: The number of years keeping livestock *($p < 0.1$);* Gender *($p < 0.05$);* Types of crops farmed *($p < 0.05$);* and 'The farmer keeps cattle' *($p < 0.1$)*. With regards to the number of years keeping livestock, a unit increase in years of keeping the livestock increases the likelihood of using the adaptation strategy "Management options" by 1.131 times than not using the base option *"Not Used (no adaptation)".* In other words, farmers who have farmed livestock longer are most likely to use the adaptation option "Management options" than not to use. While with regard to gender, the results indicate that male-headed households were 13.022 times most likely to use the adaptation option "Management options" than the base option "No adaptation". In short, male-headed households readily adapt to climate change at the household level. Regarding the types of crops farmed, farmers who practise multi-cropping are 0.49 times less likely to use the adaptation strategy "Management options". Lastly, farmers who own cattle are 19.585 times most likely to use the adaptation option "Management options" to adapt to climate change within their household.

Table 5-24: Predictors of factors influencing individual adaptation strategies at household level

	Adaptation options used in the Household								
	Used Management options			Used Behaviour options			Used Technology options		
Variables	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	.341	.893		-73.785	.989		1.760	.624	
Education	-.022	.863	.979	.279	.337	1.322	.267	.220	1.306
Years keeping livestock	**.123**	**.053***	**1.131**	**.855**	**.083***	**2.352**	**-.364**	**.034****	**.695**
Income livestock farming	.000	.939	1.000	.000	.134	1.000	.000	.466	1.000
Constituency NCS (1. North]	-.841	.502	.431	1.486	.593	4.419	1.505	.439	4.505
Constituency NCS (2= central)	-1.946	.121	.143	-.111	.963	.894	.780	.667	2.181
Constituency NCS (3= South)									
Employed (0=No: 1=Yes:]	.962	.499	2.617	2.046	.423	7.737	-1.955	.356	.142
Gender (0= Female :1 = Male)	**2.567**	**.017****	**13.022**	21.899	.996	3E+09	-.851	.565	.427
Household Size (0=<10; 1= ≥10persons)	.136	.924	1.145	1.315	.616	3.724	**6.440**	**.013****	**626.501**
Crops Farmed (0=Mono-cropping; 1= Multi-cropping)	**-3.008**	**.019****	**.049**	17.569	.996	4E+07	-1.708	.283	.181
Climate change knowledge (0 =No: 1=Yes)	.284	.871	1.328	-3.365	.439	.035	-23.845		4.41E-11
Access to Climate Information(0 =No: 1=Yes)	-.793	.561	.453	7.373	.217	1592.3	**5.906**	**.038****	**367.097**
Farm Manager (0= other]	-2.004	.138	.135	-29.206	.999	2E-13	**-4.897**	**.082***	**.007**
Farm Manager(1= Head Household)	-1.597	.159	.203	-1.362	.543	.256	**-7.638**	**.012****	**.000**
Farm Manager(2= Family Members)									
Owns cattle(0 =No: 1=Yes)	**2.975**	**.057***	**19.585**	-.005	1.000	.995	-22.538		1.63E-10
Owns goats or sheep (0 =No: 1=Yes)	-.952	.339	.386	8.320	.256	4105.8	***2.716***	***.097****	***15.123***
Observations used=278; LR chi-square=229.491 p=.000; Psuedo R^2 (Nagelkerke)=.600; Classification=65.5%									
Reference Level = Not used; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.1									

The results illustrate that only one explanatory variable, "The number of years keeping livestock" was significantly *($p < 0.1$)* associated with farmers' use of the adaptation strategy "Use Behavioural options". In fact, a unit increase in number of years of farming livestock results in an increase likelihood of 2.352 times that the household head will use the "Behavioural strategy" as opposed to "No adaptation".

With respect to the adaptation strategy, "Use technological Options", the results illustrate that six explanatory variables are significant predictors of the farmers' adaptation using the strategy "Use technological Options". These variables are: The number of years keeping livestock *($p < 0.05$);* Household size *($p < 0.05$)*; Access to climate change information *($p < 0.05$);* Who the farm manager is *($p < 0.1$);* Who the household head is *($p < 0.05$);* and Ownership of goats and sheep *($p < 0.1$)*. In relation to the number of years keeping livestock, a unit increase in the number of years of farming livestock results in a decreased likelihood of 0.695 times that the household head will use the adaptation strategy "Use technological option" as opposed to the "No adaptation". The mostly likely reason is, older farmers are less likely to use technology as compared to those with less years farming. Whilst smaller households more than 10 persons are 626.501 times more likely to use this adaptation option than not adapting. Similarly, farmers with access to climate information are 376.097 times most likely to use this strategy to adapt to climate change in their households. From this, it is evident that access to climate change information does determine farmers' adaptation strategies. Regarding who the farm manager is, where the livestock is managed by external persons the likelihood of using the adaptation strategy "Technological options" decreases by 0.82 times; whereas if the household head is the livestock farm manager the use of the adaptation strategy "Technological options" decreases by 0.0001 times. From this, it is evident that the head of household is less likely not to adapt as compared to where the households livestock is managed by 'someone" who is not a family member. Lastly, farmers who own goats and sheep are 15.123 times more likely to use the adaptation strategy "Technological options" to adapt to climate change within their household.

5.8.3.1.2 Determinants of use of Mixed Adaptation Strategies

Presented in Table 5.25 are the predictors of factors influencing mixed adaptation strategies at household level. For the combined adaptation strategy containing "Behavioural and Technology options", the results illustrate that one explanatory variable, "Farmers constituency or area of residence", significantly *($p < 0.1$)* predicted the farmers' use of this adaptation strategy. In fact, if the farmers' location was in the northern part of the Lowveld, they were 22.2times more likely to use this adaptation strategy "Behavioural and Technology options" as opposed to "Not adapting".

For the combined adaptation strategy containing "Behavioural and Management options", the results show that three explanatory variables significantly predicted the farmers' adaptation using this combined strategy. The predictor variables are: The number of years keeping livestock *($p < 0.05$)*; Gender *($p < 0.1$);* and the farmer keeps goats and sheep *($p < 0.1$).* With regards to the number of years keeping livestock, a unit increase in years of keeping livestock increases the likelihood of using the adaptation strategy "Behavioural and Management options" by 1.137 times than not using the base option *"No adaptation".* In other words, farmers who have farmed livestock longer are more likely to use the adaptation option "Behavioural and Management options" than "Not adapting". While regarding gender, male headed households are 6.178 times most likely to use the adaptation option "Behavioural and Management options" than "Not adapting". Lastly, the household heads who keep goats and sheep are 0.159 times less likely to use the adaptation option "Behavioural and Management options" than "Not adapting". These results are likely due to the fact that goat farmers are less likely to be impacted by climate change than farmers who own cattle.

Table 5-25: Predictors of factors influencing the use of mixed adaptation strategies at household level

	Adaptation options used in the Household											
	Used both Behavioural and technology approaches			Use both Behavioural and management Approaches			Used both Management and technology approaches			Used a Mixed of Management, Behavioural and technology		
	B	B	Sig.	Exp(B)	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	-3.201	.276			.713		-.225	.924		2.121	.310	
Education	.174	.260	1.190	.985	.176	.849	-.094	.428	.910	-.016	.887	.985
Years keeping livestock	.070	.262	1.073	**1.066**	**.032****	**1.137**	.035	.535	1.036	.064	.203	1.066
Income livestock farming	.000	.840	1.000	1.000	.388	1.000	.000	.691	1.000	.000	.706	1.000
Constituency NCS (1. North]	**3.100**	**.058***	**22.200**	2.546	.185	5.482	1.388	.269	4.007	.935	.388	2.546
Constituency NCS (2= central)	2.123	.183	8.356	1.602	.232	4.036	1.172	.303	3.229	.471	.620	1.602
Constituency NCS (3= South)												
Employed (0=No: 1=Yes]	1.458	.345	4.295	3.130	.730	1.632	-.223	.877	.800	1.141	.356	3.130
Gender (0= Female :1 = Male)	-1.691	.162	.184	**7.239**	**.066***	**6.178**	**2.758**	**.009****	**15.767**	**1.979**	**.017****	**7.239**
Household Size (0=<10; 1= ≥10persons)	1.841	.218	6.303	3.064	.164	6.174	1.429	.277	4.173	1.120	.366	3.064
Crops Farmed (0=Mono-cropping; 1= Multi-cropping)	-1.191	.375	.304	**.118**	**.093**	**.126**	**-2.295**	**.065***	**.101**	**-2.139**	**.065***	**.118**
Climate change knowledge (0 =No: 1=Yes)	2.302	.173	9.994	.456	.646	.457	.165	.919	1.180	-.786	.596	.456
Access to Climate Information(0 =No: 1=Yes)	-.396	.792	.673	1.163	.622	.535	-.441	.726	.644	.151	.892	1.163
Access to Climate Information =1.00												
Farm Manager (0= other]	-1.153	.419	.316	.235	.140	.105	-1.601	.242	.202	-1.447	.184	.235
Farm Manager(1= Head Household)	.102	.933	1.108	.633	.452	2.166	.463	.650	1.589	-.458	.614	.633
Farm Manager(2= Family Members)												
Owns cattle(0 =No: 1=Yes)	-19.594		3E-09	1.378	.375	3.471	-.047	.975	.954	.321	.790	1.378
Owns goats or sheep (0 =No: 1=Yes)	-1.397	.281	.247	**.258**	**.083***	**.159**	-.365	.693	.694	**-1.355**	**.092***	**.258**
Observations used=278; LR chi-square=229.491 p=.000; Psuedo R^2 (Nagelkerke)=.600; Classification=65.5%												
Reference Level = Non used; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.1												

The results show that two explanatory variables significantly predict the use of the adaptation strategy combining "Management and technological strategies", these variables are: Gender *($p < 0.1$)*, and the types of crops farmed *($p < 0.1$)*. With regards to gender, male-headed households are 15.767 times most likely to use the adaptation strategy containing "management and technological options" than "Not adapting". While households heads who practice multi-cropping are 0.101 times less likely to use this adaptation strategy as opposed to not adapting, the reason for this is multi-cropping is actually regarded as an option to adapt to climate change impacts. Hence, the farmer using multi-cropping is already practicing adaptation at the household level.

Lastly, the results for the use of the adaptation strategy that combined “Behavioural, Management and Technological strategies” indicates that three explanatory variables significantly predicted the use of this adaptation strategy. These variables are Gender *($p < 0.05$)*, the types of crops farmed *($p < 0.1$),* and if the household heads keep goats and sheep *($p < 0.05$)*.

On the subject of gender, male-headed households are 7.239 times most likely to use the adaptation strategy containing “Behavioural, Management and Technological strategies” than “Not adapting”. Whereas households heads who practise multi-cropping are 0.118 times less likely to use this adaptation strategy as opposed to “Not adapting”. Lastly, households that farm goats and sheep are 0.258 times less likely to use the adaptation option “Behavioural, Management and Technological options” than “Not adapting”. These results are likely due to the fact that farming goats and sheep is actually an adaptation option utilised for climate change adaptation.

5.8.3.2 Determinants of adaptation for livestock farming

The MNL regression results of the determinants (predictors) of climate change adaptation for livestock farming indicated that 9 out of 15 explanatory variables significantly predicted the probability of adaptation for the various strategies employed by the farmers. These variables are: Livestock farming expenses, Occupation, Years keeping livestock, Constituency, Gender, Climate change knowledge, Types of Crops Farmed, Who the farm manager is, and Goats or sheep ownership. While variables that did not significantly predict the probabilities of adaptation are: Education, Income from livestock farming, Age, Cattle death to drought or climate change, and Cattle ownership. Furthermore, the likelihood ratio statistics, as indicated by Chi-square = 179.983, was highly significant at *($p \leq .0000$),* suggesting the model’s strong explanatory power. Only those variables whose coefficients were statistically significant at ($p<0.1$) are discussed further below.

5.8.3.2.1 Determinants of use of Individual Adaptation Strategies

Presented in Tables 5.26 are the determinants of single adaptation strategies. The results illustrate that three explanatory variables significantly predicted the farmers’ adaptation strategy that uses *“Behavioural strategies*”. These variables are: The livestock farming expenses *($p < 0.05$);* who the farm manager is *($p < 0.1$);* and Ownership of goats or sheep (small livestock Units *($p < 0.1$).* With regards to livestock farming expenses, a unit increase in expenses of farming livestock increases the likelihood of using the adaptation strategy “Behavioural Strategies” by 1.0008 times than “No adaptation*”.* Simply put, farmers who spend more on livestock farming are highly likely to adapt to climate change. Another variable explaining the use of Behavioural Strategies for climate adaptation was ‘Who the farm manager is’. Where the livestock farming is managed by the household head, the likelihood of using this adaptation strategy increases by 15.959 times. From this, it is evident that the where the manager is the head of household climate change adaptation is more likely. Lastly, if the respondent keeps goats or sheep, they are 15.959 times most likely to use the adaptation option “Behavioural Strategies” for climate change adaptation within their farms than “No adaptation”.

In relation to the adaptation strategy, “Management strategies” the results show that only one explanatory variable “Keeping goats or sheep was significantly *($p < 0.1$)* associated with farmers’ use of this adaptation strategy. In fact, if the respondent keeps goats or sheep they are 2.862 times most likely to use the adaptation option “Management strategies” to adapt to climate change within their farms than “No adaptation”. So, farmers who keep goats or sheep are more likely to adapt to climate change than those who do not. This is due to the fact that farmers who keep goats or sheep are more likely aware that keeping such is actually an adaption strategy, and thus, their level of awareness to climate adaptation is higher.

The results illustrate that three explanatory variables are significantly associated with the farmers’ use of the adaptation strategy “Technological strategy”. These variables are: Livestock farming expenses *($p < 0.05$);* Occupation of the household head *($p < 0.05$);* and the types of crops farmed *($p < 0.1$).* With regards to livestock farming expenses, a unit increase in expenses of farming livestock increases the likelihood of using the adaptation strategy “Technological Strategies” by 1.0007 times than “No adaptation”. That means, farmers who spend more on livestock farming are likely (very slight) to adapt to climate change. The occupation of the household head also determines if the farmer will adapt to climate change. When the household head’s main occupation is farming, they are 6.618 times most likely to adapt to climate change and use technological strategies to adapt. Finally, where the households practise multi-cropping, they are 0.37 times less likely to use this adaptation strategy as opposed to “No adaptation”.

Table 5-26: Predictors of factors influencing single adaptation strategies for livestock farming

	Adaptation strategies used for livestock farming								
	Behavioural			Management			Technological		
Variables	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	**-38.591**	**.000*** **		-.155	.899		-1.264	.415	
Livestock Expenses	**.00008**	**.009** **	**1.00008**	.000	.809	1.000	**.00007**	**.024** **	**1.00007**
Income livestock farming	.000	.335	1.000	.000	.343	1.000	.000	.303	1.000
Education	-.068	.634	.934	-.078	.223	.925	-.100	.197	.905
Years keeping livestock	-.011	.889	.989	.028	.399	1.029	.061	.121	1.063
Constituency NCS (1. North]	-1.442	.412	.236	.708	.307	2.029	-.382	.645	.682
Constituency NCS (2= central)	-1.325	.326	.266	.200	.773	1.221	-.760	.359	.467
Constituency NCS (3= South)									
Occupation (0= 0ther: 1.00= farming)	33.215		2.66E+14	-.557	.314	.573	**1.890**	**.033** **	**6.618**
Farm Manager (0= other]	1.119	.512	3.061	-1.129	.232	.323	-.308	.733	.735
Farm Manager(1= Head Household)	**2.770**	**.060***	**15.959**	.788	.171	2.199	.368	.601	1.444
Farm Manager(2= Family Members)									
Owns goats or sheep (0 =No: 1=Yes)	**2.357**	**.075***	**10.555**	**1.052**	**.078***	**2.862**	-.983	.287	.374
Cattle death to climate change. (0 =No: 1=Yes)	-1.321	.482	.267	-.150	.814	.861	-.030	.969	.971
Climate change knowledge. (0 =No: 1=Yes)	1.528	.400	4.609	-.162	.823	.851	-1.040	.283	.354
Gender (0= Female :1 = Male)	2.219	.191	9.196	.001	.998	1.001	-.647	.314	.524
Age=.(0 =young 18-39: 1=>39)	1.603	.328	4.968	.309	.666	1.362	1.388	.116	4.006
Crops Farmed (0=Mono-cropping; 1= Multi-cropping)	-1.015	.371	.362	-.570	.263	.566	**-.995**	**.093***	**.370**
Owns Cattle (0 =No: 1=Yes)	**3.351**	**.074***	**28.535**	.448	.630	1.565	-.577	.671	.562
Observations used=278; LR chi-square=179.983; p=.000; Psuedo R^2 (Nagelkerke)=.494; Classification=50.4%									
Reference Level = No Change; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.1									

5.8.3.2.2 Determinants of Use of Mixed Adaptation Strategies

Presented in Tables 5.27 are the determinants of mixed adaptation strategies. The results indicate that no explanatory variable was significantly associated with farmers' adaptation using the combined adaptation strategies, "Behavioural and Management strategies, and Behavioural and Technological strategies".

The results demonstrate that, two explanatory variables were significantly associated with the adaptation strategies that combined "Management and Technological strategies". These variables were: Livestock farming expenses *($p < 0.05$)*, and the years of farming livestock or experience *($p < 0.05$)*. In relation to livestock farming expenses, a unit increase in expenses for farming livestock increases the likelihood of using the combined "Management and Technological strategies" for adaptation by 1.0006 times than "No adaptation". In short, farmers who spend more on livestock farming are most likely to adapt to climate change. To add, for the number of years keeping livestock (experience), a unit increase in experience increases the likelihood of using the adaptation strategy "Management and Technological strategies", by 1.066 times than not using the base option “No adaptation”. Therefore, the more experienced farmers are most likely to adapt to climate change.

Table 5-27: Predictors of factors influencing mixed adaptation strategies for livestock farming

	Adaptation options used for livestock farming											
	Behaviour and Management			Behaviour and Tech			Management and Tech			Mixed all 3		
Variables	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Intercept	-1324.575	.932		-2.448	.218		-.283	.796		**-4.351**	**.002****	
Livestock Expenses	-.177	.412	.838	.000	.608	1.000	**.00006**	**.029****	**1.00006**	**.00005**	**.069***	**1.00005**
Income livestock farming	.014	.394	1.014	.000	.647	1.000	.000	.291	1.000	.000	.334	1.000
Education	38.387	.653	4.7E+16	-.096	.353	.909	-.073	.194	.929	-.055	.401	.947
Years keeping livestock	-2.268	.902	.104	.050	.360	1.051	**.064**	**.032****	**1.066**	**.087**	**.014****	**1.091**
Constituency NCS (1. North]	298.288	.966	4E+129	.132	.906	1.141	-.226	.703	.798	**1.605**	**.061***	**4.979**
Constituency NCS (2= central)	556.000	.938	3E+241	.251	.817	1.285	-.434	.457	.648	1.335	.110	3.800
Constituency NCS (3= South)												
Occupation (0= 0ther: 1.00= farming)	-463.564	.428	5E-202	.425	.658	1.530	-.507	.303	.602	-.025	.966	.975
Farm Manager (0= other]	-106.388	.994	6.3E-47	-.078	.952	.925	-.198	.760	.820	-.159	.836	.853
Farm Manager(1= Head Household)	-171.832	.710	2.4E-75	1.275	.150	3.578	.577	.265	1.781	.929	.131	2.532
Farm Manager(2= Family Members)												
Owns goats or sheep (0 =No: 1=Yes)	-708.558	.959	0.000	.347	.728	1.415	-.121	.829	.886	.679	.293	1.971
Cattle death to climate change. (0 =No: 1=Yes)	508.707	.498	8E+220	-.737	.492	.479	.614	.265	1.847	.241	.706	1.272
Climate change knowledge. (0 =No: 1=Yes)	389.906	.507	2E+169	.386	.718	1.471	-.865	.202	.421	**-2.333**	**.050***	**.097**
Gender (0= Female :1 = Male)	173.039	.990	1.4E+75	-.086	.921	.918	.560	.264	1.751	**1.121**	**.096***	**3.068**
Age=.(0 =young 18-39: 1=>39)	-568.395	.953	1E-247	1.590	.167	4.903	-.080	.900	.923	.879	.227	2.407
Crops Farmed (0=Mono-cropping; 1= Multi-cropping)	561.163	.723	5E+243	-.475	.550	.622	-.291	.523	.748	-.387	.477	.679
Owns Cattle(0 =No: 1=Yes)	-15953.9		0.000	.407	.778	1.502	.191	.819	1.211	.931	.311	2.536
Observations used=278; LR chi-square=179.983; p=.000; Psuedo R^2 (Nagelkerke)=.494; Classification=50.4%												
Reference Level = No Change; Significance: ***= *p*<.001; **= *p* <.05; *= *p*<0.1												

Finally, for the combined adaptation strategy containing “Behavioural, Management and Technological strategies”, the results demonstrate that four explanatory variables were significantly associated with this strategy. These variables were: Livestock farming expenses *($p < 0.05$);* the farmers’ constituency (area of residence) *($p < 0.1$)*; the farmers’ knowledge of climate change *($p < 0.1$);* and Gender *($p < 0.1$)*. On livestock farming expenses, a unit increase in expenses for farming livestock, increases the likelihood of using this combined adaptation strategy by 1.00005 times than “No adaptation”. In other words, farmers who spend more on livestock farming are more likely to adapt to climate change. In relation to constituency, or location of residence, the farmers whose location was in the northern part of the Lowveld of Eswatini were 4.979 times more likely to use this adaptation strategy “Behavioural, Management and Technology strategies” as opposed to “No adaptation”. The farmers’ knowledge of climate change, on the other hand, reduces the likelihood of using this adaptation strategy by 0.97 times as opposed to “No adaptation", while gender or male-headed households are 3.068 times more likely to adapt to climate change by using this combined strategy.

5.8.4 Summary of determinants of adaptation

Variables that influenced adaptation to climate change at the household level included: Years keeping livestock, Constituency, Gender, Household size, Types of crops farmed, Access to climate information, Who the farm manager is, Cattle ownership, and Goats or sheep ownership. The results indicated that 9 out of 15 explanatory variables significantly predicted the probability of adaptation using various strategies by livestock farmers and these variables are: Years keeping livestock, Livestock farming expenses, Occupation, Constituency, Gender, Climate change knowledge, Types of crops farmed, Who the farm manager is, and Ownership of goats or sheep .

In conclusion, the results for climate adaptation at the household level and livestock farming level indicated that at the household level, it was influenced by 8 variables while for livestock farming it was influenced by 9 variables. Six variables were found to influence both (adaptation at the household level and the livestock farming level). These common variables were: Years keeping livestock, Constituency, Gender, Types of crops farmed, Access to climate change information, who the farm manager is, and Ownership of goats or sheep. In addition, at the household level predictors of adaptation were: Household size, Access to climate information, and Cattle ownership; while at the livestock farm level additional variables that determined adaptation were: Livestock farming expenses, Occupation, and Climate change knowledge.

The variables that enhanced (positively influenced) climate change adaptation at the household level were the following: Years keeping livestock (experience), Constituency (location), Gender (males), the household head owning cattle, and the household size (large households). Contrary, the variables that decreased (negatively influenced) the likelihood of the respondents adopting a certain climate change adaptation strategies at the household level were: Who is the farm manager is, the Types of crops farmed, and Farmers who practised multi-cropping. However, where the household head owned goats or sheep influenced the adoption of climate change adaptation strategies either positively or negatively, depending on the strategy. For example, it has a positive influence on the single strategy "Technological approaches" and negative for mixed strategies combining either "Behavioural and Management or Behavioural, Management and Technology".

For livestock farming and climate change adaptation, the variables that enhanced climate change adaptation are: Years keeping livestock, Livestock farming expenses, Occupation, Constituency, Gender (male), Climate change knowledge, Types of crops farmed, Who the Farm Manager is, and Goats or sheep ownership (Small Livestock Units. Only two variables negatively influenced the likelihood of the farmers adopting a certain climate change adaptation strategies for their livestock farming, and these were: Knowledge of climate change and Farmers practicing multi-cropping.

The positive findings are similar to those of scholars like Silvestri *et al*. (2012), Deressa *et al*. (2009), and Adeagbo *et al.* (2021) with regard to farm income, household size, agro-ecological setting (constituency), and access to climate change information; and to Deressa *et al.* (2009) and Adeagbo *et al.* (2021) with regard to gender, farm income, and livestock ownership. On the other hand, the negative findings on the variable, "Climate change knowledge" are opposite to the findings of Adeagbo *et al.* (2021). The results for practicing multi-cropping are also opposite to the findings of Borokini *et al.* (2014), and an in-depth discussion of these results is presented in the following chapter (Chapter 6).

5.8.5 Barriers to climate change adaptation by farmers

The farmers revealed that there were several impediments to adaptation, and the leading impediment was lack of awareness, followed by not knowing what to do (lack of know-how), then the lack of information, and finally the lack of money.

A cross-tabulation was performed to examine the association between the farmers' response to whether they had adapted their livestock farming or not, and the barriers to adaptation. From the cross tabulation of these variables (see Table: 5.28), three variables were significantly associated with the farmers responses if they adapted or not, and these were: Lack of information *($p < 0.05$)*, Lack of awareness *($p< 0.01$),* and Lack of know-how *($p< 0.01$)*, with only lack of financial resources being insignificant.

Based on these findings, it is evident that to intensify climate change adaptation, the farmers need to be trained and capacitated to increase their awareness and know-how on climate change, and once they understand they can be provided with information to address this. Even though financial resources were not significant, most adaptation requires them. This is supported by reasons for not adapting put forward by Ifejika Speranza *et al*. (2010), who concluded that for successful adaptation to climate change by the agro-pastoralists, it was crucial to address the constraints between vulnerability and poverty, because knowledge of climate change alone was not sufficient to generate significant adaptations by the farmers. Thus, any approach to increase adaptation should focus on these barriers.

Table 5-28: Association between farmers' reasons to adapt and for not adapting

Variable		Adapted to climate change Impacts								
		Yes	%	No	%	Total	%	statistics		
Lack of Information on how to adapt								X^2 =	df =	*Sig.* =
	Agree	93	*37*	85	*33*	178	*70*	7.441	2	0.024**
	Not sure	27	*11*	9	*4*	36	*14*			
	Disagree	26	*10*	14	*6*	40	*16*			
	Total	146	*57*	108	*43*	254	*100*			
Lack of Financial Resources								X^2 =	df =	*Sig.* =
	Agree	120	*47*	95	*37*	215	*85*	3.324	2	.190
	Not sure	6	*2*	5	*2*	11	*4*			
	Disagree	20	*8*	7	*3*	27	*11*			
	Total	146	*57*	107	*42*	253	*100*			
Lack of Awareness on adaptation								X^2 =	df =	*Sig.* =
	Agree	66	*26*	83	*33*	149	*59*	25.991	2	.000**
	Not sure	26	*10*	10	*4*	36	*14*			
	Disagree	54	*21*	15	*6*	69	*27*			
	Total	146	*57*	108	*43*	254	*100*			
Lack of Know how								X^2 =	df =	*Sig.* =
	Agree	73	*29*	92	*36*	165	*65*	36.201	2	.000**
	Not sure	30	*12*	11	*4*	41	*16*			
	Disagree	43	*17*	5	*2*	48	*19*			
	Total	146	*57*	108	*43*	254	*100*			

5.8.6 Summary on adaptation to climate change

Given that climate change adaptation involves describing, whether proactive or reactive adjustments, in natural and human systems in response to current or anticipated climate changes to minimize damage or enhance benefits; in evaluating this adaptation by the farmers, the following analysis and results were obtained. Two approaches were used: 1) evaluate the farmers' adaptation at the household level; 2) then regarding their livestock farming. The results indicated that at the household level there were 10 adaptation measures and the dominant ones used were: Water harvesting and storage, varying crops planting dates, selling livestock, using drought tolerant crop varieties, diversifying crops, and using agricultural extension services. Whereas for livestock farming, there were 16 adaptation options, and the main ones used were: Providing medicines and pesticides, selling livestock, water harvesting and provision, seeking training, and engaging in mixed crop systems.

The various adaptation approaches for both household and livestock farming were grouped into three categories: Behavioural, Managerial or Technological in line with Silvestri *et al*. (2012)

categorisation of farm level adaptations. The result combinations of these strategies were seven, and the dominant strategy for household adaptation was a combination of all three strategies used by 61% of the households. For livestock farming, the dominant strategy was a combination of Management and Technology used by 41% of the farmers.

Using the MNL Regression Model and the various adaptation approaches, and a list of socio-economic demographic variables, the determinants of adaptation at the household level and livestock farming level was obtained. At the household level 9 out of 13 explanatory variables affected the probability of adaptation and these included: Years keeping livestock, constituency, gender, household size, types of crops farmed, access to climate change information, who the farm manager is, cattle ownership, and goats or sheep ownership; while for livestock farming, 9 out of 15 explanatory variables significantly explained adaptation for the various strategies employed by the farmers. These variables were: Livestock farming expenses, occupation, years keeping livestock, constituency, gender, climate change knowledge, types of crops farmed, who the farm manager is, and goats or sheep ownership. In most cases and similar to findings by other scholars, these variables had positive influence on adaptation with the exception of a few.

There were a number of household heads who stated that they did not adapt at either the household or livestock farming level, and the reasons they gave for such were due to deficiency of information, lack of awareness, deficiency of know-how, and shortage of financial resources. Using a cross tabulation and Chi-Square, these were tested with the "Whether the farmers adapted or not" and a significant association.

5.9 Climate forecasts and their use in adaptation

According to Wilk *et al*. (2017), seasonal climate forecasts have become an essential part of disaster and risk planning, and agricultural early warning systems. By using forecast information, farmers can reduce drought risks and also adapt to climate change (Klopper *et al*., 2006: Dorling, 2014). One of the objectives of this study was to establish if knowledge of and access to climate forecasts influenced livestock farmers climate change adaptation strategies.

To solicit information on use of climate change information, data was collected using the questionnaire from all household heads who participated in the study. The data collected using the questionnaire allowed for the exploration of relationships between variables collected. The data collected is presented using descriptive statistics below. In addition, semi-structured interviews with seven (5 males and 2 females) key informants selected from the community were conducted using the Key Informant Interview guide (see Appendix 1). The key informants were community leaders who also farmed livestock, and were deemed to be the most appropriate in contributing information about the utilisation of seasonal climate forecasts. The data collected from the interviews was analysed using Thematic analysis and summarised in table A.6 (see Appendix 6). Initially, it was planned that the bulk of this information on farmers' use of forecasts was to be obtained from the farmers using FGDs and a Participatory approach. However, due to restrictions on gatherings due to COVID-19, the data was collected using the Key Informant Interviews. Presented first is the data analysis of data on "Use of climate data by all farmers and adaptation".

5.9.1 Farmers access to information on climate change

The results revealed that with regard to access to climate change information, which in most cases related to climatic data or forecast data and its impacts, 78% of the farmers had access to such information, and 22% did not, while 76% of the farmers indicated that they had access to climate change information relevant to livestock farming, with 24 % indicating they did not (see Figure 5.35).

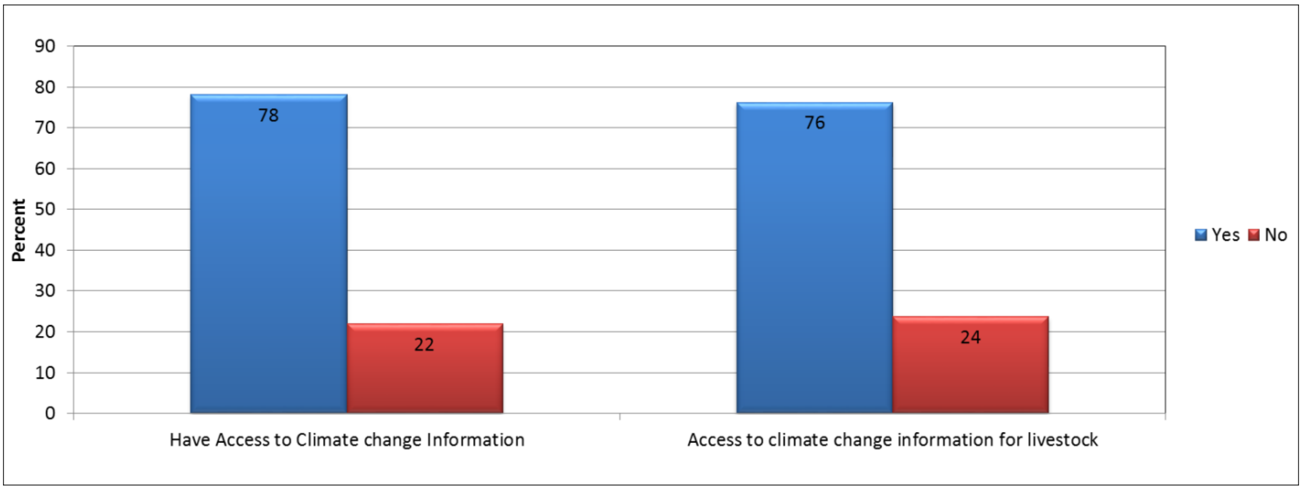


Figure 5-35: Farmers access to climate information

5.9.2 Time frame of Climate information received

The farmers were then asked to specify the time-frames (short term, medium term and long term) for which they received climatic data. The results indicated that the majority (70%) of the farmers reported that they received short-term information on temperature, but for rainfall only 55% received medium term information. For weather information, the majority (49%) reported receiving short term, followed by 42 % for medium term, and 9% for long term. Finally, for climate information, 43% received medium term, 32% short-term, and 25% long term (see Figure 5:36). When considering these results, it can be established that the farmers are relatively aware of the different climate forecasts; reason being that they receive weather forecasts and they can unpack them into different components, for example, temperature, rainfall, weather and climate.

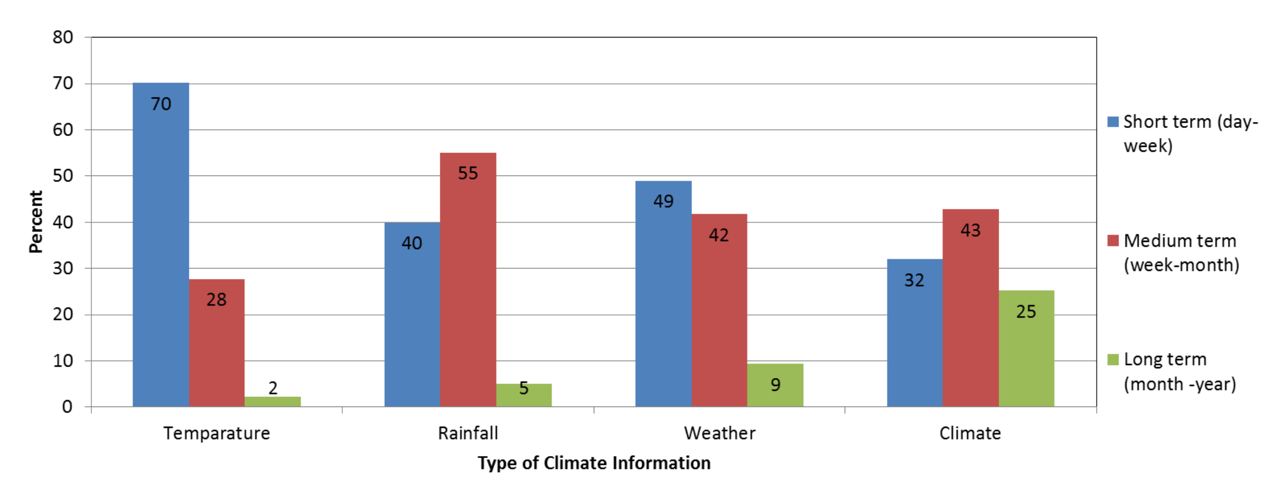


Figure 5-36: Time-frame for climate information received by the farmers

5.9.3 Farmers use of weather and climate information

The farmers were requested to rank how they had used the weather or climate forecast information they had received as a decision making tool for their livestock farming. The results are presented graphically in Figure 5.37. The popular significant agreeable use of the information was for disease and pest management reported by 91% of the farmers. Second was to provide supplementary feeding reported by 84% of the farmers; third was for information when to cull livestock reported by 77% of the farmers; forth was for planned breeding (calving) reported by 68%; and lastly was for use in planned breeding and restocking reported by 57% of the farmers.

A number of farmers stated that they were unsure with the use of climate or weather information for farming operations; for instance, for planned breeding activities and restocking activities 28% of the farmers indicated they were not sure how to use the climate information. Whereas 17 % indicated they were not sure how to use the information for culling; 9% for supplementary feeding; and 8 % for disease and pest management.

Those who disagreed with the use of climate information for livestock farming activities were as follows: For planned breeding (calving) 4%; for supplementary feeding 7%; for pest and disease management 1%; for culling 6%; and for restocking 15%.

From these results, it was evident that farmers who are not sure about the use of forecasts tend to increase during normal farming operations (planned breeding and restocking) when about 28% are not sure of their use, and about 57% agree with their use for restocking, while 68% agree with their use for planned breeding. Nevertheless, during periods of extreme climatic events like droughts, when farmers have to either to supplementary feed their livestock or provide disease and pest management solutions or eventually cull the livestock, their agreeable use of weather or climatic information increases, and during such times to between 77-91%. From this observation, it is obvious that most of the farmers did or did not know that weather and climate forecasts can be employed as tools for climate change adaptation.

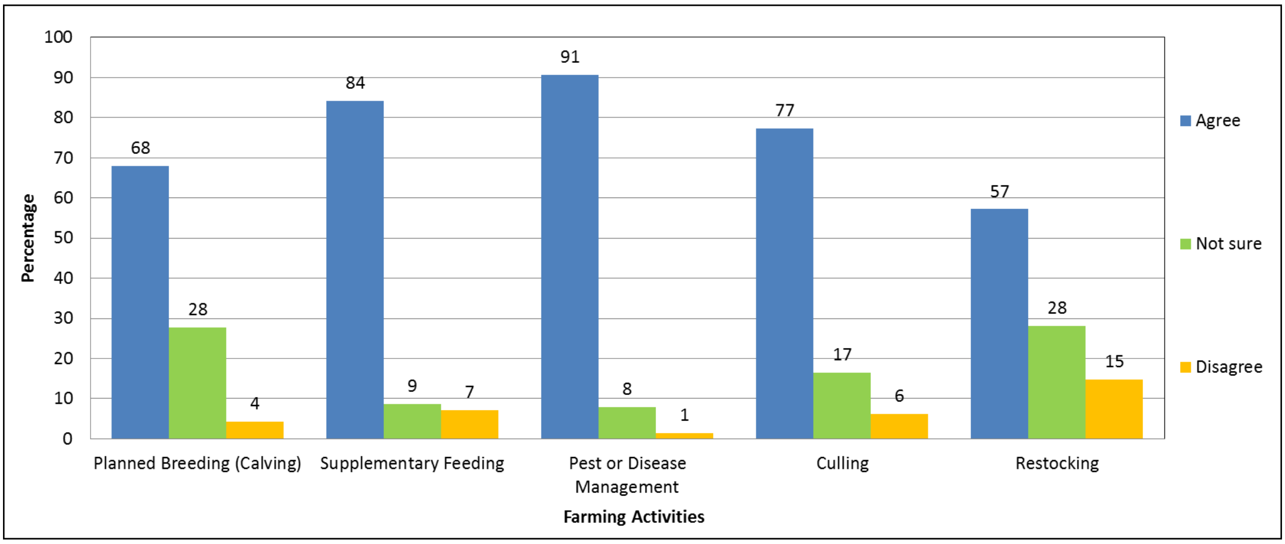


Figure 5-37: Farmers use of climate information for livestock farming

5.9.4 Farmers knowledge and use of seasonal climate forecasts

The key informant farmers were asked for their responses to a number of questions and their responses were summarised thematically as outlined in Table 5.29, and more elaborate in Appendix 6.

5.9.4.1 <u>The impacts of climate change</u>

The first discussion point was on their experiences of the impacts of climate change on agriculture (see Table 5.29). The key informants indicated that climate change in their respective areas has been severe, especially two key informants stated that in the last El- Nino some homesteads lost over 40 head of cattle and "*after such ordeals some farmers give up on livestock farming"* or worse "*we have had cases of farmers committing suicide because the losses are too much to bear.* But overall, some key informants became emotional when talking about climate change impacts. In summary, they highlighted the following as climate change impacts on farming: Partial or total failure of dry land crops, livestock deaths especially cattle, reduced grazing, reduced water availability, change or shifts in the rain season – especially delayed rains, an increased need for supplementary feeding, and shortages of supplementary hay in the market. Other information gathered was that the government's assistance with supplementary feed would focus on farmers with very few cows (five cows or less). Anyone with larger numbers was deemed to be commercial and had to fend for themselves. Regarding this, one key informant said, *"This is one policy failure of government because they fail to assist farmers who actually contribute to the country's GDP".*

Table 5-29: Summary of key informant responses on use of forecasts

Questions	Key Informant s Response Summary
Let's talking about the impacts of climate change on your farming activities	• Severe impacts on both crops and livestock i.e. Dry land Crop failure during droughts and Livestock deaths during droughts and El Niño • Reduced grazing, and water availability and Increased need for supplementary feeding • Shifts in rain season
What adaptations have been utilised to adapt to climate change?	• Provide water and supplementary feeding • Diversified crops and livestock (Keep other livestock goats, chicken etc.) • Sell or cull livestock. Plant early and Used drought tolerant crop varieties • Seek external income (Employed, businesses) and Use input from extension services and climate forecasts
Have you heard about seasonal climate forecasts?	• Yes – they more inclined to dry land crop production and less to livestock farming
How have seasonal climate forecasts assisted you to adapt to climate impacts?	• Mainly used for dry land crop farming, choosing the seed varieties and when to plant. Or what to plant • They misleading or unreliable at times • less used for livestock farming but are used to plan supplementary feeding with regard how much feed might be needed and when to culling
Have you heard about long term climate projections?	• Yes – but not in detail – mainly for Eswatini (increased temperature and reduced rainfall) – and they not specific to each area
What do long term climate projections indicate for you as a farmer?	• Lot of uncertainty- not sure • Farming will be more challenging, It Might get costlier to farm • Need to adjust or adapt the way we will farm
Share with the farmers the a seasonal forecast Seek how they will react to these.	• Don't fully trust these- wait and see • Cull and Sell cattle to minimise loses • Supplementary feed livestock , Need to provide medicines • Need to provide water for winter stock watering • Plan adaptation or farm activities in line with this information
Share with the farmers the latest climate projections Seek how they will react to these.	• Difficult to plan for its way in the future • Central and southern region • Farming more expensive and risky • There will be less grazing And water • Plant drought tolerant grain and Diversify livestock • Need to invest in more resilient livestock e.g. goats • Need to invest in livestock watering • Northern region • Wetter might be better suited for current agriculture • Will spend less on supplementary fodder Might be easier to farm
Suggest ways and means in which climate	• Forecast difficult to understand thus More training is required for them to understand them

forecast and projections can assist you better manage your livestock farming?	• Forecasts not specific for livestock farming, But more information is on dry land crop farming they need to address this. The Forecast should also be area specific • The forecast have reliability issues- (during last el Niño farmers were told it will be a normal year and they lost their crops) • Forecasts need to be timely – shared early so the farmers can make informed decisions • They can assist plan for the future activities on the farm such as when to sell livestock how much and for how long fodder is needed • These should also be used by government to come with initiatives to assist the farmers. • They can assist reduce expenditure which could be exerted by good planning

5.9.4.2 Measures used to adapt to climate change impacts

The results indicated that a number of adaptations were implemented by farmers themselves; some of these were proactive adaptation such as diversifying both the crops they grew as well as their livestock; for example, they also keep other livestock such as goats, pigs, and chickens. For their crops, they used either drought tolerant seeds or early maturing varieties. Furthermore, they rely on information on forecasts and associated extension services' advice on what to plant based on seasonal forecasts. Some farmers also culled livestock before the winter season, whereas others would also seek for farm income through employment and businesses. One key informant reported that: "*I have scaled back my cattle farming due to the impacts of the last El Nino and now focus on farming indigenous chickens and my transport business*". Reactive approaches include supplementary feeding during food shortages, providing water for stock watering.

5.9.4.3 Knowledge of seasonal climate forecasts

All key informants indicated knowledge of seasonal climate forecasts, but indicated that the forecast information and extension advice they received from these focussed mainly on dry land crop farming, which informed them on the start of the rainy season, the climatic outlook, and what to grow. With regard to livestock farming the advice either comes too late when cows are dying, and it is difficult or sell the livestock.

5.9.4.4 Have seasonal climate forecast assisted in climate adaptation?

"Yes the seasonal forecast are used especially by dry land crop farmers who use them to inform on seed varieties and when or not to plant". They are, however, less used for livestock farming, but when they are informed on time they use these to cull and also to plan for supplementary feeding in the winter months when the grass is limited. The main source of such forecast is the radio where the ministry's extension services inform farmers on the seasonal climatic outlook.

While stating that these are used for crop farming, the majority of the key informants stated that *"the information and extension advice based on these forecasts shared is not always reliable and misleading".* (Recently the extension services issued advice to farmers stating they must engage in crop farming because the forecast is above normal rainfall; the farmers heeded the advice but most did not harvest because of a drought).

5.9.4.5 Knowledge of long term climate projection

They indicated they had little knowledge that temperatures will get hotter, and there will be less rain.

5.9.4.6 What do long term climate projections indicate for you as a farmer?

The key informants indicated multiple answers from not being sure of what will happen in the future due to these projections to stating that "*Farming will be more challenging and it might get costlier to farm".* Another response was that *"There will be need to adjust or adapt the way we will farm".* Some of the informants indicated that this subject was difficult to comment on because it is way in the future, and as such lot of uncertainties exist.

5.9.4.7 Reaction to actual seasonal forecasts

The key informants were presented with a seasonal forecast and it was explained to them, and following this presentation, they were asked to comment on how they would adapt their livestock farming based on such a forecast. The reactions varied but major adaptations mentioned were as follows: One informant stated that "*The problem with such forecasts is we do not fully trust them, they misleading and not specific, therefore I would wait and see"*. Other adaptations suggested were: They would cull unproductive animals to reduce the burden for supplementary feeding; they have to plan and provide supplementary feeding and medicines (supplements and pesticides) for their livestock; they also have to plan for and provide for livestock watering in winter. Lastly, they would plan farm livestock farming activities in line with this information. These suggestions meant that farm operations that required additional resources would be halted, and they would focus on sustaining the existing livestock.

5.9.4.8 Reaction to actual climate projection

Regional climate projections and those for Eswatini to the year 2050 were shared with the respondents and their views on how they would adapt their livestock farming based on such a forecast. Of note in the projections is that the southern part of the Lowveld of Eswatini is likely to be hotter and dryer, while the northern part will be likely wetter. The reactions from those in the central and southern part were that, even though it was difficult to plan way into the future, but it was more likely that they will plant more drought tolerant grain; for example, sorghum instead of maize. *"This means there will be less water and grazing so we might have to invest in more resilient livestock such as goats which also browse on trees".* Others mentioned the lack of water and the need to invest in livestock watering such as rainwater harvesting or use of groundwater.

Those from the northern part of the Lowveld of Eswatini, which is projected to be wetter, stated that they would continue as normal because the projections are that the situation they are currently in might get better, which means having more grass and water. Therefore, it will better suit their farming operations, and this will mean less money spent on supplementary feeds and stock watering in winter.

5.9.4.9 Suggestions on how climate forecast and projections can assist in livestock farming

The key informants were quizzed on suggestions of techniques to improve the use of climate forecasts in their livestock farming. They stated that forecasts can assist in planning farming operations and reducing risks and costs. There was almost general consensus amongst them in that these seasonal forecasts need to be tailored for livestock farming, similar to what is done for dry land crops. There was also a need for training and capacity building of the farmers, for them to understand and use these forecast. The forecasts need to be reliable and timely, that is, "*They must be shared early so the farmers can make decisions when there is still time".* Another suggestion was: These forecasts and associated extension advice should be area specific and not general. Lastly, government was also to come up with assistance to the livestock farmers tailored around climate forecasts.

5.9.5 Summary of farmers access to and use of climate forecast

One of the objectives of this study was to establish if knowledge of and access to climate forecasts influenced livestock farmers' climate change adaptation strategies. In order to answer this objective, a number of these sub-question had to be answered: 1) did the farmers have access to climate change information? The majority of the farmers revealed that they had access to climate change information, most of which they received through radio and television. Fewer farmers, however, indicated that the information they received was of relevance to livestock farming. 2) The farmers were quizzed on the time-scales they associated with each information especially forecasts, and this was relevant to determine if they had understanding of the different types of forecasts. Their responses indicated their awareness; for example, temperatures were received for the short term, rain medium term, weather forecasts were mainly short term, while climate was for medium and long term. All the farmers were quizzed on how they use of climate information for selected livestock farming activities. From the responses, it was evident that most the farmers agreed with the use of climate forecasts as tools to mitigate the impacts of climate variability and change. Lastly, a more in-depth view on the knowledge and use of climate forecast was sought from the key informants in the community. The results of these interviews indicated that the impacts of climate change on livestock farming varied between areas, with some areas reporting more livestock losses, but overall, the impacts of climate change and variability were significant, and in most cases the farmers reported adaptation measures. With regard to the knowledge and use of seasonal climate forecasts, all the informants were aware of seasonal forecast as they are mainly used as extension service support to dry land crop farming; however, they raised issues with their reliability. They mentioned seasonal forecasts were less used for livestock farming, but when they are informed in time and they use them to cull /sell unproductive livestock and also to plan for supplementary feeding in the winter months when grass is limited.

The farmers' reaction to the use of actual seasonal forecasts also indicated issues related to reliability, while also indicating that they would cull /sell unproductive animals to reduce the burden for supplementary feeding, and they have to plan for other adaptation operations such as stock watering, supplementary feeding provision of medicines, and supplements and pesticides for their livestock. They would also halt other operations that require additional resources and focus on sustaining the existing livestock.

With regard to practices to improve the use of climate forecasts for livestock farming, the main procedures or practices need to involve: Training and capacity building of the farmers, for them to understand and use these forecast; the forecast need to be reliable, timely and specific (area specific).

From the results it was evident that the use of seasonal forecast in agriculture is common for dry land crop farming but less common for livestock farming. For livestock farming the uses tend to be for proactive uses such as planning for projected impact of a drought and implementing culling or planning resources to cater for supplementary feeding.

5.10 Evaluation of climate change adaptation policies

Policy evaluation or analysis is one way of evaluating climate change, especially from a Top-down approach, that is, from the government to the people. This study made use of Thematic and Content analysis, as employed by scholars such as Muchuru and Nhamo (2017) and England *et al.* (2018), to determine policies that assist farmers' adaptation practices to climate in the Lowveld of Eswatini.

In addressing the research question regarding existing policies within the country that are meant to assist the livestock farmers adapt to climate change impacts, the various policies related to livestock farming were reviewed. In total nine, nine policies were reviewed for adaptation measures aimed at addressing climate change adaptation (see Table 5.30). The policy documents were purposefully sampled, using criteria that the documents must be sector specific and address livestock farming within Eswatini, and contain matters connected to climate and or climate change.

Table 5-30: List of policy documents reviewed

Name of document	Source
The Kingdom of Swaziland's Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC).	Government of Eswatini (GOE) website
National Climate Change Policy, 2016	GOE website
National Development Strategy (NDS) 1997 -2022	GOE website
Livestock Development policy 1995	GOE website
National Food Security Policy for Swaziland 2005	GOE website
Comprehensive Agriculture Sector Policy, 2005	GOE website
National Drought Mitigation And Adaptation Plan (NERMAP) 2016-2022	NDMA website
National Development Plan 2019/20	GOE website
Swaziland Resilience Strategy and Action Plan (SRSAP), 2017	NDMA website

These documents were then subjected to a literature survey methodology that employed Thematic analysis as well as Content analysis in relation to climate, impacts, change, adaption and livestock. Using this methodology the Content analysis was utilised to code and categorize large texts from the national policy documents and reports by determining first trends and patterns of the utilised words, their relationships, and their frequency; while the Thematic analysis was used to identify, analyse and report on the adaptation themes within reports. The themes captured the adaptation measures from the various policy documents and the different contexts used to adapt livestock farming to climate change. These themes were then studied and interpreted to make sense and make conclusions. The adaptation themes used were modified by the author based on themes identified by other scholars such as Muchuru and Nhamo (2017) as well as literature on adaptation by scholars such as Howden *et al.* (2007), Ifejika-Speranza *et al.* (2010), Thornton (2010), and Silvestri *et al.* (2012). In total, ten thematic areas were developed and used, and from these themes, a 251 adaptation interventions emerged. Table 5.31 presents the total number of categories of adaptation interventions in each of the themes used.

Table 5-31: Adaptation themes and categories of adaptation interventions

Adaptation Themes	Total number of categories of adaptation interventions
Capacity building and, training, awareness and information sharing	46
Technology, research and development	40
Policies	36
Rangeland and pasture management	30
Livestock breeding, diversification and intensification and marketing	29
Carrying capacity management and improvement	18
Disease and parasites management	15
Alternative livelihood and diversification	13
Institutional development and strengthening	12
Water supply	12
Total	251

5.10.1 Key findings of the content and thematic analysis

Outlined below are the results of the content and thematic analysis.

5.10.1.1 <u>Adaptation themes and adaptation interventions from the analysis</u>

The key findings of the thematic and content analysis are outlined per adaptation theme starting with the adaptation theme with the highest number of adaptation categories. As outlined in Table 5.31 (for more detail refer to Appendix 4**),** the theme with the highest number of adaptation categories is:

(i) *Capacity building and training, awareness and information sharing.* Capacity building in these policies refers to improving the farmers'/ institutions'/ teams' ability to perform and achieve aims over time. For example, the policies realise that for farmers to adapt: training, information sharing, extension support, and awareness creation are needed. Thus, in total all the policies reviewed identified this aspect as the most important for adaptation.

(ii) *Technology, research and development,* which focuses on how technology and innovation can assist the farmers adapt; for example, using technology such as early warning mechanisms, and research, and the development of new breeds or technologies for rangeland grazing management.

(iii) *The development of Policies*. Policies were identified as key in adaptation; for example, there was a need to develop a number of laws (acts and regulations) to operationalize existing policies. Currently, most of the documents, reports or policies reviewed lacked operationalization instruments; for example, rangeland management policies exist but there is no legislation to implement or enforce them.

(iv) *Rangeland and pasture management* which focuses on grazing lands and their management. As most rangelands in Eswatini are communal, their management is paramount for climate change adaptation. It is vital to minimise long term degradation due to over grazing, or setting out improper livestock handling facilities such as dip tanks.

(v) *Livestock breeding, diversification, intensification and marketing.* There is a drive across all the policies to intensify livestock farming; this intensification is linked to breeding breeds that can adapt, but also yield better returns for the farmers.

(vi) *Carrying capacity management and improvement*. This theme discusses what could be done to improve carrying capacity of grazing lands; for example, replanting palatable grasses, using rotational grazing, and the creation of communal grazing lands fencing funds.

(vii) *Disease and parasites management*. Disease and pests management is of importance to climate change adaptation. Thus, this theme focuses on issues that look at improving livestock disease and pest management. Interventions include: implementing a livestock identification system; monitoring the importation of livestock; improving the institutions that deal with pest and disease management; and the development of economical animal health services appropriate to the farmer's needs.

(viii) *Alternative livelihood and diversification*. To minimise the impact of climate related shocks, diversification is used. In the case to the policies in Eswatini, diversification includes: supporting the farming of small ruminants, pigs, and poultry for personal consumption and commercialization, and to encouraging diversification of high value cash crops or alternative sources of income such as bee-keeping.

(ix) *Institutional development and strengthening and provision of water.* Institutional support includes employing better equipped extension officers, decentralisation of veterinary support to the creation of institutions to better organize the farmers. While provision of water includes: assisting the farmers with livestock water such as earth dams to boreholes and water harvesting techniques on the farm.

5.10.1.2 Adaptation interventions per policy

From the thematic and content analysis, the number of adaptation interventions per policy was determined to establish how each policy addressed adaptation. The findings are outlined in Table 5.32 (for a more detail refer to Appendix 4). From this it is evident that the policies with the highest number of interventions were The Comprehensive Agricultural Sector Policy (2005); The Livestock Policy (1995); The National Development Strategy (1997-2022), and The National Food Security Policy (2005). The Comprehensive Agricultural Sector Policy had a higher number of interventions mainly because it deals with mixed farming methods; whilst the livestock sector only focuses on livestock; but generally, most livestock farmers in Eswatini practise the mixed farming methods.

Also evident from this analysis is that climate adaptation in livestock farming is highlighted as an important strategy for the Government of Eswatini, in that it focuses a lot in the National Development Strategy (1997-2022), and is, thus, identified as a key aspect of national development with regard to agricultural development. Furthermore, climate adaptation in the livestock sector is also important in ensuring food security in the country as highlighted by the themes in the National Food Security Policy. With regards to the other policies, adaptation in the livestock sector does not feature as much, mainly because these policy documents are cross-cutting and focus on an array of sectors.

Table 5-32: Cumulative thematic adaptation interventions per policy reviewed

Policy Documents Reviewed	Cumulative number thematic adaptation interventions per policy
Comprehensive Agriculture Sector Policy, (2005)	78
Livestock Development policy (1995)	59
The National Development Strategy (1997-2022)	26
National Food Security Policy for Swaziland (2005)	21
Swaziland's Third National Communication to the UNFCCC.	19
Swaziland Resilience Strategy and Action Plan (SRSAP) 2017	14
National Climate Change Policy, 2016	13
National Drought Mitigation and Adaptation Plan (NERMAP) 2016 -2022	11
National Development Plan 2019/20 – 2021/22	10
Total	**251**

From the results of this analysis, it is evident that policy documents (statements) that deal with climate change adaptation in the livestock farming are comprehensive; however, there was little evidence of these documents being operationalized; for example, putting them into legislation such as acts or regulations that are enforceable by law. All the Acts or laws that deal with livestock precede these policy documents.

5.10.2 Famers input into required policies

In their evaluation of policies, Urwin and Jordan (2008) use two types of approaches: Top-down and a Bottom-up approach. Similarly, the Bottom-up approach was used in this study where the farmers were requested to identify key policy interventions that could be utilised for climate change adaptation for livestock farming.

5.10.2.1 *Recommended policy options from farmers*

The farmers were requested to rate the policy considerations that they would suggest government to develop and implement to assist them with climate change adaptation. Figure 5.38 outlines the policy options in terms of rank: (1) being the highest priority, and (7) being the least. According to all the farmers interviewed, the policies were ranked as follows:

1. Government assistance with provision of livestock markets
2. Provision of training and capacity building on all aspects related to livestock farming and climate adaptation
3. Provision of improved early warning systems (such as specific seasonal climate forecasts),
4. A need for improved grazing land - most communal lands are overgrown with alien species and bush encroachment
5. Having climate proofed livestock systems
6. Assistance with access to livestock services infrastructure such fencing, dip tanks, and watering facilities
7. Breed diversification and drought relief provision.

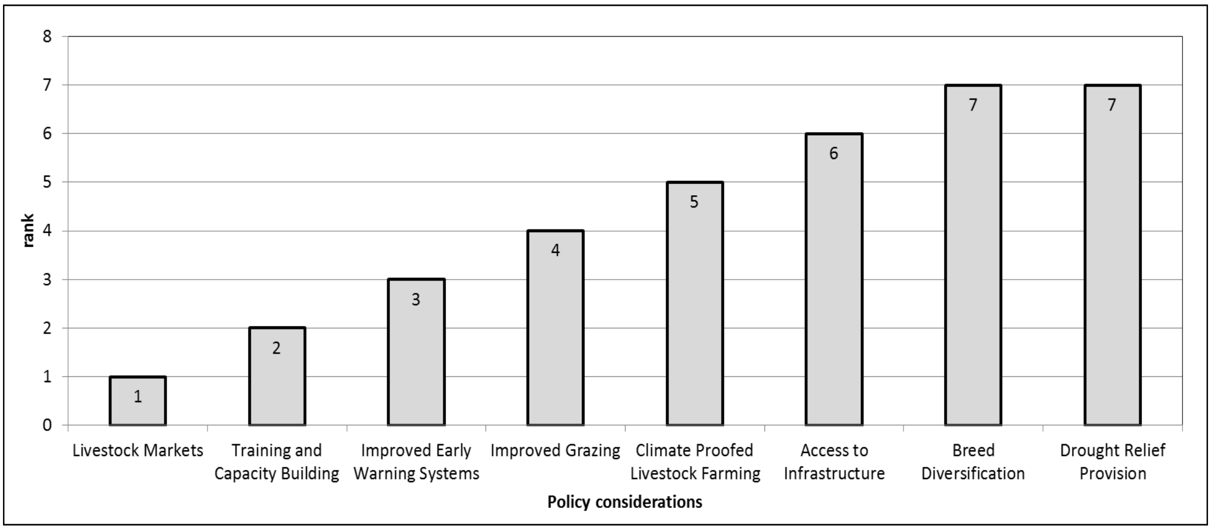


Figure 5-38: Policy considerations for future polices from famers

5.10.2.2 *Relationship between policy considerations and adaptation*

A cross-tabulation was carried out to examine the association between whether farmers had adapted their livestock farming or not, and the policy considerations they would want to be implemented by government to assist them adapt. The reason was to determine which policy options were significantly associated with adaptation. From the cross tabulation (see Table: 5.33), five policy options were significantly associated with the farmers response if they had adapted or not and these were: Breed diversification ($p < 0.05$), Drought relief provision ($p< 0.05$), Improved grazing ($p< 0.05$), Training and capacity building ($p< 0.1$), and Improved early warning systems ($p< 0.1$); while Livestock markets, Climate proofed livestock farming, and Access to infrastructure were insignificant.

Table 5-33: Association between policy considerations and adaptation

Policy option	Suggested	Adapted %		Total	X^2	df	Sig.
		Yes	No				
Livestock Markets	Agree	54	36	90	3.230	2.00	0.199
	Not sure	4	3	6			
	Disagree	3	0	3			
Breed Diversification	Agree	50	36	85	**6.537**	**2.00**	**0.038****
	Not sure	9	4	12			
	Disagree	3	0	3			
Training and capacity building	Agree	54	37	92	**4.820**	**2.00**	**0.090***
	Not sure	4	2	6			
	Disagree	2	0	2			
Drought Relief Provision	Agree	49	36	85	**7.570**	**2.00**	**0.023****
	Not sure	9	3	12			
	Disagree	3	0	3			
Improved Early warning Systems	Agree	53	36	88	**4.669**	**2.00**	**0.097***
	Not sure	6	4	9			
	Disagree	3	0	3			
Climate Proofed livestock farming	Agree	51	36	87	3.121	2.00	0.210
	Not sure	7	3	9			
	Disagree	3	1	3			
Improved Grazing	Agree	52	37	89	**6.939**	**2.00**	**0.031****
	Not sure	7	2	9			
	Disagree	2	0	2			
Access to infrastructure	Agree	52	35	87	2.015	2.00	0.365
	Not sure	7	4	11			
	Disagree	2	0	3			

5.10.3 Policies for adaptation in the Lowveld of Eswatini

From this evaluation, it was obvious that farmers who adapted and those who had not adapted had different priorities with regard to policies. To ensure that no farmers are omitted in climate change adaptation strategies, it was deemed appropriate to separate their policy options.

5.10.3.1 *Policies to be considered for all farmers to climate change*

The ranked policies from the Top-down approach analysis were combined with those identified by the farmers as required to assist them adapt, and were then ranked after the combination (see Table 5.34). These policies in terms of rank from the most important are:

1. Training and capacity building,
2. Improved early warning systems,
3. Provision of livestock markets,
4. Improved rangeland and pasture management
5. Climate proofed livestock farming,
6. Drought relief provision (policies),
7. livestock breed diversification
8. Provision of access to livestock farming infrastructure.

Table 5-34: Policy options to consider for adaptation for all famers

Policy options	Thematic analysis rank (1)	Farmers rank (2)	sum (1+2)	rank (1+2)
Drought relief provision (policies)	3	7	10	6
Improved rangeland and pasture management	4	4	8	4
Livestock breed diversification	5	7	12	7
Training and capacity building	1	2	3	1
Improved early warning systems	2	3	5	2
Livestock marketing	5	1	6	3
Climate proofed livestock farming	3	5	8	4
Access to infrastructure	10	6	16	8

5.10.3.2 *Policies to be considered for farmers who have adapted*

The ranked policies from the Thematic and Content analysis were combined with those identified by all the farmers as required to assist them adapt, and the association between adaptation policy options identified by the farmers. All these policies were ranked, and the top significant policies were presented as policies options to be implemented to assist the farmers adapt (see Table 5.35). These policies in terms of rank from the most important are:

1. Training and capacity building,
2. Improved rangeland and pasture management
3. Improved early warning systems
4. Development or implementation of policies on drought relief assistance
5. livestock breed diversification

Table 5-35: Policy options to consider for adaptation by rank

Policy options	Thematic analysis rank (1)	Farmers rank (2)	sum (1+2)	rank (1+2)	sig. to adaptation rank (3)	Sum (1+2+3)	Rank (1+2+3)
Drought Relief Provision (policies)	3	7	10	6	1	11	4
Improved Rangeland and pasture management	4	4	8	4	2	10	2
Livestock breed Diversification	5	7	12	7	3	15	5
Training and capacity building	1	2	3	1	4	7	1
Improved Early warning Systems	2	3	5	2	5	10	2
Livestock Marketing	5	1	6	3	Not sig.		
Climate Proofed livestock farming	3	5	8	4	Not sig.		
Access to infrastructure	10	6	16	8	Not sig.		

5.10.4 Summary on policy analysis

In this study, a combined Top-down approach and Bottom-up approaches was used to identify, prioritize and evaluate adaptation policy options in conjunction with stakeholder prioritized criteria. The Top-down approach involved the use of Thematic and Content analysis, to determine policies that assist farmers' adaptation practices to climate change in the Lowveld of Eswatini. In total nine (9) policy documents were reviewed for adaptations measures. The Bottom-up approach used data obtained from all the respondents in the study. The Prioritized adaptation options from both the Top-down and Bottom-up approaches were combined using ranking, and they yielded two sets of results: those for farmers who have not yet adapted and those who have adapted.

The five key adaptation options to be considered for policy implementation for all farmers (both adapted and non-adapted) are: Provision of training and capacity building; assisting farmers with Improved early warning systems; Provision of livestock markets; Improved rangeland and pasture management and Climate proofed livestock farming; and Drought relief provision. However, the policy considerations for farmers who have adapted their livestock farming, the five key adaptation options were highlighted as a top priority to assist them better adapt in the Lowveld of Eswatini. These options are: Training and capacity building, Improved rangeland and pasture management, Improved early warning systems, Development or implementation of policies on drought relief assistance, and Livestock breed diversification.

During the Bottom-down approach, it is evident that most policy documents (statements) that deal with climate change adaptation in the livestock sector are comprehensive; however, there was little evidence of these documents being operationalized into legislation; thus, there is a need to operationalize these into legislation

5.11 Chapter summary

The results of the study indicate that based on meteorological data covering 31 years, the climate of the Lowveld of Eswatini has significantly changed. The livestock farmers interviewed are all engaged in mixed farming where they grow a crop or other crops. There was variance in how farmers perceived temperature and rainfall across different locations, but in general their perception was that the Lowveld has got hotter and rainfall has decreased, with an increase in droughts and change in the rainy season; though the farmers' perception does not always correlate with empirical data. The majority of farmers perceive that climate change has negatively affected their household as well as livestock farming, and the impacts vary by activity and respondent. While faced with these challenges of climate change, the majority of farmers are adapting in spite of barriers such as insufficient knowledge of how to adapt. The adaptation approaches used vary from farmer to farmer and by location. The adaptation options for either household adaptation or livestock farming were grouped into three categories, namely: Behavioural, Management and Technical strategies. Hence, the farmers used one or a combination of these resulting in eight different strategies. The modelling indicated that a number of socio-demographic variables are predictors of perception and adaptation. Common predictor variables included: gender, location, experience, and livestock income or expenditure. With regards to the utilisation of climatic information and seasonal forecasts, the farmers tend to use seasonal forecasts for crop farming and less for livestock farming because these forecasts are developed mainly for crop farmers. Farmers' access to future climate forecast does not alter their adaptation approaches but assist in planned adaptation. The farmers highlighted the need for training on the use of seasonal forecasts and also the need for specific, reliable, and timely livestock forecasts to assist them adapt to climate change. Lastly, presented were the results on policy evaluation whose results indicated that there was poor implementation of policy on adaptation mainly because of a lack of a legislative framework. Furthermore, the farmers identified policy options they would want government to implement for them to adapt. These recommendations were combined with those from the Content and Thematic analysis of policy documents, and the three most important policy options for consideration were: Training and capacity building, improved early warning systems, and provision of livestock markets.

The next chapter is the discussion of results.

CHAPTER 6

DISCUSSION OF RESULTS

6.1 Introduction

This study intended to investigate climate change impacts on livestock farming and determine adaptation options used, together with investigating how access to long term climate forecasts influenced the farmers' climate adaptation strategies. These objectives were achieved by answering four research questions posed by the study and these being:

(i) How is livestock farming in the Lowveld of Eswatini affected by climate change?

(ii) What climate change adaptation measures are used by livestock farmers in the Lowveld of Eswatini?

(iii) How does the knowledge of, and the availability of access to future climate forecasts and projections influence farmers' climate change adaptation strategies in the Lowveld of Eswatini?

(iv) What are proposed climate adaptation policy guidelines to assist livestock farmers adapt to climate change?

The aim and associated research questions were addressed and the findings are presented in Chapters 5 in the following order: 1) climate trends in the Lowveld of Eswatini; 2) the analysis of bio-demographic data of the respondents; 3) the farmers' climate change perceptions and its impact on their livelihood activities; 4) the respondents adaptation strategies employed at the household and livestock farming level; 5) how farmers react to seasonal forecasts and projections and the proposed adaptations they would use; and 6) the proposed policies to assist the farmers, particularly in the Lowveld of Eswatini, adapt to climate change impacts. The present chapter considers in detail the outcomes or key results of the research, and also outlines the implications of the outcomes in the light of other studies or the theoretical and empirical literature. The discussion of findings is organised into seven sections drawing on the findings presented in Chapter 5, and also on the main themes that arise from the research objectives and associated questions.

6.2 Discussion on climate trends in the lowveld of Eswatini

The climate of the Lowveld of Eswatini has significantly changed over a 31 years period (1988-2018). Two climatic indicators, temperature and rainfall, were used in the evaluation. With regard to temperature the mean annual temperatures in the northern part of the Lowveld (using Mhlume as a proxy) has significantly declined by 0.46ºC over the 31 years. Furthermore, there was a significant decline in spring temperatures. On further scrutiny, the maximum temperatures have significantly declined for annual temperatures as well as the winter season, while there was no significant change in minimum temperatures. Contrary, in the southern part of the Lowveld (using Big Bend as a proxy), the mean annual temperatures have significantly risen by 0.9ºC over the 31 years. Furthermore, the winter temperatures also significantly increased. A further scrutiny indicated a significant rise in maximum annual temperatures and the winter season, while for minimum temperatures there was a significant rise in annual temperatures as well as the winter and autumn season.

With regard to rainfall, a significant decline was seen for the summer rainfall in the northern part of the Lowveld, with no significant change for annual rainfall. Similarly, no significant variations in annual rainfall were recorded in the south and central parts, but there were significant variations in monthly rainfall for the southern part where June's rainfall had significantly decreased, while in the central regions' June and October rainfall also significantly declined.

These results for temperatures for the southern part of the Lowveld are relatively similar to those observed by Archer *et al.* (2010) who pointed out that the Sub–Saharan region has been realizing a heating trend over the last decades. Also similar to these results are those of Nkondze *et al.* (2014) who also did a similar study in the Lowveld and indicated that temperatures have been steadily increasing, and there was a lot of variation in rainfall. The rise in temperatures over the 31 years for the southern part of the Lowveld is significantly higher than the rise in global average surface temperatures for 132 years, where temperature rose by 0.85 °C for the period between 1880 to 2012 (IPCC, 2013). In the northern part of the Lowveld, the findings are divergent from these findings and can be explained by the undulating topography which can cause many variations to regional temperature. Such is similar to the findings reported in the Kingdom of Swaziland's Third National Communication in 2016 to the UNFCCC where it is reported that the temperatures in the Lowveld of Eswatini region will increase with a probably greater increase in summer than winter; however, some regional variations to temperature increase will occur due to Eswatini undulating topography (Government of Swaziland, 2016).

With regard to rainfall, the outcomes are much like those of Nkondze *et al.* (2014) whose similar study in the Lowveld showed that there was a lot of variation in rainfall. Similarly, the Kingdom of Swaziland's Third National Communication Report in 2016 to the UNFCCC noted that there is great variability in rainfall, while in the long term down-scaled projections indicate negative changes over most parts of the country and a positive change over the northern part of the country (Government of Swaziland, 2016). These findings concur with a study on drought in Eswatini, by Mlenga *et al*. (2019) using SPI analysis of droughts from 1986–2017, that observed that droughts in the lowveld had increased in terms of their incidence, severity and geospatial coverage, furthermore, there was also great variability on both temporal and spatial scales across the country as well as the agro-ecological zones. While another study, investigating the temporal variability of droughts in Eswatini using the Standardised Precipitation Index for analysing precipitation data between 1981 and 2018, by Tfwala *et al.* (2020) concluded that droughts in Eswatini and especially the Lowveld have increased in prevalence and severity since the year 2000 secondly; that the frequency of droughts is higher in the dryer areas (e.g. Lowveld) as compared wetter areas (e.g. Highveld); and lastly, that the trends of were generally increasing. Also observed in the report (Third National Communication Report in 2016 to the UNFCCC) was that there were drier winters and a decline in the spring months rainfall, indicating a delayed rain season over the country. It must also be noted that variations in rainfall are also related to Southern Africa's current climate drivers, such as the El Niño Southern Oscillation. Thus, studying the impact of such extreme events (El Niño) on rainfall might yield better understanding of rainfall patterns in the Lowveld of Eswatini. This observation is sustained by suggestions of Groisman *et al*. (2005) who proposes that in comparison to normal climate trend analysis, changes in extremes climate events are more expected to be used for future climate change analysis. Furthermore, studies on extreme temperature trends in Western, Central, and Southern Africa, that used extreme events to indicate climate change, displayed growths trends for heat waves and declining trends for cold spells (New *et al*., 2006).

6.3 Comparison of climate trends and farmers perceptions of climate change

Weber (2010) states that the public's general perception of climate change and variability is usually based on their observations of climatic variables that affect their lives. In this study, questions about perceived changes of temperature, rainfall, incidences of hot and cold days, incidences of the drought, wind and floods of an extended period of time were used to gauge the farmers' climate change perceptions.

The results demonstrated that the perception amongst the livestock farmers was that the climate had changed. The results indicated that, in general, the farmers perceived that the following climatic variables were increasing: temperature, hot days, drought severity, drought frequency, and winds; while the climatic variables, rainfall, rain days, the rain season, cold days and floods were perceived to decrease. Furthermore, there was spatial variance in how farmers perceived climate change across different locations. The results also indicated that there was a significant relationship between constituency (place of residence) and the farmers' perception to rainfall and temperature.

The farmers perceptions with regard to temperature and rainfall were compared with the climatic trend data discussed above. The results of this comparison for temperature in the northern part of the Lowveld (using Mhlume mean temperatures as a proxy) did not fully support the notion that temperatures were increasing with the exception of one month, while the farmers' perception and trend data for the southern part indicated an increasing temperature.

With regards to rainfall, there was a decline of rainfall in the northern part of the Lowveld, though not significant, but there was a significant reduction in summer rainfall as well as a significant decline in December and February rainfall. Similarly, there was no significant change in the annual and seasonal rainfall in the southern and central parts, but there were significant shifts in monthly rainfall for the southern part, where June's rainfall had significantly decreased, while in the central part, the June and October rainfall also significantly declined.

These results on the farmers' perception are similar to those of Maddison (2007), who surveyed farmers in 11 countries across the African continent, and the results concluded that the vast majority of farmers suggested that temperatures had already risen and rainfall had dwindled. Correspondingly, research by Debela *et al.* (2015) on perceptions of climate change by smallholder agro-pastoralist in Ethiopia, indicated that these farmers perceived that the climate had changed with elevated temperatures, below-average precipitation, and a curtailed wet season. Another study by Mulenga *et al*. (2017), in Zambia, indicated that farmers felt that Zambia had grown warmer, and there was a change in rain season, and a surge in the rate of within season dry spells. Equally, the results of a study by Gebeyehu *et al.,* (2021) showed that agro-pastoralists in the Lower Omo Valley of Ethiopia perceived an increasing temperature, increased dry season, and a decrease in rainfall amount, including more frequent droughts. Correspondingly Idrissou *et al*. (2020a) studying cattle farmers in Benin revealed that farmers' main perception of climate was reduced rainfall and an increase in temperature and strong winds. The farmers perceptions on drought are in line with the findings of a study on droughts in Eswatini, using the Standardised Precipitation Index (SPI) on data from 1986–2017 revealed that droughts have intensified in terms of their frequency, severity over this period, (Mlenga *et al*., 2019; Tfwala *et al*., 2020).

When compared to the actual climatic records, the farmers' perceptions did not always correspond with empirical data. For example, in the northern part of the Lowveld temperatures are actually significantly declining with the exception of the month of June that is significantly increasing. These findings for the northern part are not similar to those of Mulenga *et al*. (2017), Gebeyehu *et al*. (2021), Snaibi *et al*. (2021) and Habte *et al*. (2022) but are actually opposite except for the month of June, but are true for rainfall. The inconsistency separating farmers' perception of temperature and actual climatological data can also be explained by an observation by Ovuka and Lindqvist (2000) who noted that scientists often analyse climate data at different time-frame intervals than those used by farmers which include crop growing season, causing conceivable deviations in farmers' perceptions and actual data. It is the researcher view that because the farmers actually received less rainfall in the summer season, the drought experience became more frequent, and thus, it was difficult for the farmers to differentiate between temperature increase from increase in drought frequency. To them drought is perceived as the temperatures that have increased. Such perceptions need further studying to determine if the farmers are able to distinguish between climate change related droughts such as hydrological, meteorological, and agronomic droughts.

With regard to rainfall, the empirical results indicate great variability in the annual results; though these are insignificant. There are, however, a significant decrease in either seasonal (summer) rainfall or in certain months. The farmers' perceptions are almost contrary to this in that most perceived a decline in rainfall. These results for annual rainfall are similar to those of Debela *et al.* (2015) from smallholder agro-pastoralist in Ethiopia where the participants indicated that rainfall declined, but this was not substantiated by meteorological evidence. These results are also similar to findings from Zambia where Mulenga *et al*. (2017) reports that, even though the perception was that there was significant decrease in rainfall, the empirical evidence indicated great variability, and suggested a more indefinite correlation. Thus, the rainfall data did not support the perception concerning the rainy season duration and frequency of droughts. Debela *et al.* (2015) offers reasons for such perceptions and notes that other factors such as genuine localised change, increased climate variability, and climate extremes may be modifying the farmers' perception. For example, a recent experience of severe drought drives a belief that climate has significantly changed. This observation concurs with this study in that the farmers' perception data was collected within the backdrop of the severe 2015-2016 El Nino, which is believed to have influenced the farmers' perception towards rainfall and climate.

Lastly, there was no marked decline in yearly rainfall; however, the rainfall amounts in certain months or seasons declined significantly, and the farmers' perception was of reduced rainfall. This observation can be explained by a finding by Blench (2005) that witnessed a resembling divergence amongst the public's perception on rainfall and the meteorological data. This divergence was accredited to the difference in actual rainfall and drought measurement versus the publics' measurement, where the actual scientific measurement emphasize a meteorological drought whereas the publics' measurement focuses on agronomic drought.

6.4 Discussions of predictors of farmers perceptions of climate

Almost all the farmers indicated that they perceived climate change impacted negatively on all their livelihood activities except for family health where they were divided in opinion. Similarly, the majority of the farmers (79%) indicated that their livestock farming was impacted by climate change. To further understand the farmers' perceptions in the Lowveld of Eswatini on climate change impacts, both the Chi-square tests and the MNL regression modelling were utilised.

The results indicated the majority of the farmers (89%) had knowledge on climate change, and 76% indicated they had access to climate change information relevant to livestock farming. The major sources of climatic information were radio, television, family and neighbours, newspapers and social networks. These results on awareness are similar with the findings of other scholars such a Mandleni and Amin (2011), Ajayi (2014), and Ado *et al.* (2019) who reported awareness ranging between 84 and 86% while studying farmers' awareness and perception on the African continent. Similarly, Ajayi (2014) reported the radio as the main source (used by 81% of respondents) of information on climate change.

On further scrutiny, the farmers' knowledge of climate change was found to be significantly associated with the following socio-demographic variables: age, education, household size and income from livestock farming. The knowledge of climate change and access to climatic information is actually an indicator of education (formal or informal) which is associated with climate perception. In fact, scholars such as Debela *et al*. (2015) agree with this finding and state that studies from various places in Africa show that significant benefits arise from local climate information shared with farmers, and this increases their knowledge and appreciation of climate change relating to informed adaptive choices and enhanced technology usage.

The MNL regression was used for exploring the predictors of climate change perceptions among the livestock farmers. The results indicated that no variables significantly predicted the farmers' perceptions of temperature, while for their perceptions of rainfall, the variables age, and constituency (area of residence) were the predictors of increased rainfall perception among the livestock farmers. Whereas for the perceived changes in the rainfall season, six explanatory variables, namely: education, number of years farming livestock, age, types of crops farmed, who the farm manager is, and farmers' constituency or area of residence were the significant predictors of perception of a change in the rainy season among the livestock farmers. The predictors of an increase in rain season were: education, age, and farmers' constituency or area of residence. The variables that were predictors of a shortened rain season were: number of years farming livestock, age, types of crops farmed, who the farm manager is, and farmers' constituency or area of residence. Whereas one explanatory variable, constituency, was the predictor of the livestock farmers' perceptions of an increase or decrease in drought frequency. The perceived "increase in wind" was significantly predicted by four variables, namely: age, household size, who the farm manager is, and constituency or area of residence. While the perception "decreased wind" was significantly predicted by two variables, constituency and the marital status of the farmers. These findings are similar to those of cattle farmers from Benin done by Idrissou *et al.* (2020a) which also revealed that factors determining farmers perception of climate change were; cattle farmers experience, the farmers education and the household size. The differences noted were for, membership of a farmers' association and herd size which were not included in the study analysis.

With regard to the farmers' perceptions, the variable "age" was a positive predictor of "increased rainfall", "increase" or "decrease in rain season", and a negative predictor of "increase in winds". Education was a negative predictor of an increase in rain season. These outcomes are comparable with those of Mamba *et al*. (2015) and Debela *et al.* (2015) who found that education and age influenced farmers' rainfall and rain season perceptions, where the older and more literate farmers are inclined to perceive rainfall accurately as opposed to younger and less literate farmers. From this, it is evident that age of the farmer, which can also be a proxy for experience, and education increase the farmers' knowledge of climate change.

Relating to the "constituency or area of residence" it was evident that spatial setting has a considerable effect on the farmers' perceptions of climate. Actually, constituency was the most common predictor of perception for all the climate variables; furthermore, its influence varied from region to region. A similar observation was made by Habtemariam *et al.* (2016) while studying climate change perceptions amongst farmers in Ethiopia, where there was a significant relationship between many of the perception categories and location. The main reason is that local settings and experiences about climate can influence the farmers' perceptions about climate change. Such findings are reminiscent to the findings of Haq and Ahmed (2020) who observed that people's familiarities with their area of origin' extreme weather events affects their climate change perceptions. This proved true, especially for the farmers from the northern part of the Lowveld who were likely to predict a "decrease in rainfall", and a "decrease in rain season". When these are compared with the actual data, the rainfall in the north has decreased by 30% (not significant), and there was a significant decline in summer rainfall. From this it is evident that actual climate trends and constraining climatic experiences to one's livelihood do influence the farmers' perception, similar conclusions were made by Deressa e*t al.* (2011) and Habtemariam *et al.* (2016).

The "household size", the "farm manager" and "if the farmers practiced multi-cropping" were also predictors of the farmers' perceptions about climate variables. Given that such activities as to who manages the farm or if they practice multi-cropping are linked to the farmers' behaviour and to a likelihood of climate adaptation, where large families (households) have a higher degree of adapting to climate change, it can be concluded that adaptation practices are associated with farmers' perceptions, and thus, are predictors of perceptions. For example, it is argued that, expanding household size raises the probability of adaptation, and this view implies that a large family size is connected to higher labour which enables the household to adapt to climate change.

6.5 The farmers perceived impacts of climate change

Generally, the farmers indicated that they noticed that climate change or variability had a negative impact on their activities. At the household level, the majority of the farmers reported that they perceived that climate change had an adverse impact on crop yields, household income, availability of domestic water, and an increase in diseases amongst their family members; except for climate change impacts on family health, where 50% of the farmers reported a decrease in family health. These conclusions resemble those by Popoola *et al.* (2018) that revealed that farmers, in the Eastern Cape Province, South Africa, perceived climate change had resulted in reduced crop quality and yield, water scarcity, increased diseases, and a loss of farm income earnings. Similar conclusions were also made by Ado *et al. (*2019) on farmers from Niger and Habte *et al.* (2022) in Southeastern Ethiopia.

Most (over 70%) farmers revealed that they perceived climate change had damaging impacts on livestock farming activities which included the following: grazing, water available for livestock, milk production, birth rates of their livestock, and an increase in livestock pests and diseases, and an increase in the livestock death rate. Overall, 78% of the farmers stated they perceived climate change had a detrimental impact on livestock farming. These results, to a certain extent, reflect on those of a study in Malawi on cattle farmers who perceived that climate change resulted in an increase in pests (72% of the respondents), and reduced milk production (70% of the respondents), but differ with regard to a decrease in calving rates and increased death rate which was reported by only 40% of the farmers (Chingala *et al.,* 2017).

6.6 The predictors of climate change impacts

Two MLN Regression models were employed to further explore the predictors of climate change impacts on the livestock farmers' households and livestock farming. The results indicated that nine explanatory variables were predictors of farmers' perception that climate change affects their household; eight of these variables are predictors that climate change impacts negatively on the household. These predictor variables are: education, farmers' constituency or area of residence, employment (is the farmer employed), gender, occupation, who the farm manager is, ownership of cattle, and ownership of goats and sheep, if the farmer lost livestock (cows) to drought. Whereas the variable that predicts climate change impacts positively on the household was found to be the farmers' employment status.

For the climate change impacts on livestock farming, positive impact predictors were non-existent, while the negative impact predicators were: education, gender, household size, access to climate information, and who manages the farm, which were are all positive predicators of the negative impact. To add, the non-ownership of cattle is a predictor of the farmers perceiving that climate change has 'no impacts' on livestock farming.

Regarding the variables that are predictors of climate change impact on the household and livestock farm, "education" was a predictor of a negative impact on both the household and livestock farming. At the household level education reduced the likelihood of predicting negative impact but increased the likelihood for predicting a negative impact for livestock farming, as discussed above that education increases the farmers' knowledge of climate change. Therefore, farmers with higher levels of education are very likely to interpret and use climate information on their livelihood affairs. In this case, more educated farmers are less likely have their household exposed to climate change impacts when compared to less educated farmers. Educated farmers are also more aware and knowledgeable of climate change and its impact on livestock farming, and are more likely to predict a negative climate change impact on livestock farming. This conclusion is related to that of Habtemariam *et al*. (2016) who note that the positive relation between perception and education is expected because farmers' higher education levels result in superior perception skills which enable the farmers to better evaluate climate and make decisions grounded on observation and information. Similarly Simpson *et al*. (2020) states that climate change knowledge incorporates being aware of both climate change and its causes, which thus strengthens informed adaptation reactions and accordingly, education increases adaptation reactions.

Similarly, male respondents were more likely to predict a negative impact on the household or livestock farming, mainly because they are most likely more educated and knowledgeable of climate and its impact. This finding is similar to that of Simpson *et al*. (2020) who noted that gender was also found in several countries (Nigeria, South Africa and Tunisia) to impact on climate change perception, with women having lower literacy. The study observation is in contrast of a study in Eswatini by Mamba (2016) who noted that female farmers were more exposed to local conditions because in the developing countries agriculture is dominated by female farmers since men emigrate to work; and thus, females are better perceivers of climate change impacts. In this study, however, male farmers tend to dominate livestock farming.

Spatial location (constituency) of the respondents also influenced their perception of climate change impacts on the household. Households in the northern part of the Lowveld of Eswatini were more likely to predict negative climate change impacts on the household, while those in the central part were not as likely to do so. As discussed above, local settings and experiences about climate can influence the farmers' perceptions about climate change; farmers in the northern part were more exposed to a significant reduction in summer rainfall when compared with the other parts, and thus, tend to have faced more impacts of climate change. Hence, their likelihood of predicting that climate change has negative impact on their household. Similar conclusions were made by Haq and Ahmed (2020) when they concluded that home area extreme climates influence climate change perceptions.

Respondents who are employed, and whose main occupation is not farming, are less likely to perceive that climate change impacts on their households. The reason for this is that these respondents are less exposed to climate change impacts because they also depend on external sources of income; hence, climate change impacts on the household are minimal. These results are similar to those of a study by Deressa *et al*. (2011) who observed a positive association for agricultural income and farmers' climate change perceptions, but they are contrary to those of Debela *et al*. (2015) who noted that non-income fails to significantly change farmers' perceptions of climate change and its effect on farming. From this, it is evident that farmers with diversified sources of income are not as likely to be impacted by climate change because off-farm income buffers income losses and adverse climate change impacts. Therefore, in an effort to reduce the effects of climate change in farming, farmers should also focus on diversifying their income streams to minimise exposure to climate change.

A household's ownership of cattle, goats and sheep, and having lost cows to drought reduces the likelihood of the respondent predicting that climate change has negative impacts on the household. This is probable because the household has adapted their livestock farming to climate change impacts. For example, farmers who have lost livestock to drought are probably more aware of adaptation measures than those who have not and are, therefore, less likely to highlight the climate change impact on their household. These findings are in line with a statement by Ifejika-Speranza (2010) who states that ownership of livestock: cows, goats and sheep is associated with financial well-being, and thus, adaptation to agricultural technologies requires some form of financial well-being. This financial well-being status also assists the farmers with better access to information, and they can have a longer term planning horizon; meaning, they will perceive that climate change has fewer impacts.

For considering climate change impacts on livestock farming, these variables: access to climate information, household size, and a farm manager that is head of the household are positive predictors of a negative climate change impact on livestock farming. Access to climate information raises the farmers' awareness of climate change and the likelihood that they understand climate change impacts on their livestock. Similarly, for larger households it is argued that, a growing household size raises the odds of adaptation, and this means that, the larger household is more likely to be aware of climate change impacts. This result contradicts that of Silvestri *et al.* (2012) and Debela *et al*. (2015) who found that household size was non-significant in terms of predicting perceptions to climate change. Similarly, where the manager is the head of household, awareness of climate change impacts on livestock is raised because of ownership as opposed to somebody hired. Lastly, the farmers' ownership of cattle reduces the likelihood of the respondent predicting a negative climate change impact on livestock farming. This may likely be because the household has adapted their livestock farming to climate change impacts. These results are similar to those of Ifejika-Speranza (2010) who states that ownership of cows is associated with financial well-being and adaptation to agricultural technologies, but opposite to the findings by Debela *et al*. (2015) who found that livestock ownership and holding, particularly cattle, was linked with a positive climate change impact perception because of the reliance to livestock which is climate-sensitive to pasture and water.

6.7 Discussions of results on adaptation to climate change

Climate change adaptation at the micro or farm level focuses on tactical decisions farmers make to counter changes in climatic, economic, and other factors (Di Falco *et al.,* 2012). Maddison (2006) and Deressa *et al.* (2011) state that climate change adaptation involves two actions which comprise perceiving that climate is changing, then reacting to these changes through adaptation. As discussed in the perception section above, the farmers perceived a change in climate, and furthermore, empirical trend data has indicated that the climate in the Lowveld of Eswatini is changing. Thus, understanding the approaches, strategies, and predictors of adaptation is paramount for the development of any policy interventions that can enhance adaptation. Therefore, the discussion on adaptation will focus firstly on adaptation amongst the farmers and barriers to adaption; followed by the approaches used for climate change adaptation; then the strategies used for adaptation, and lastly the predictors of adaptation.

6.7.1.1 Adaptation amongst the farmers and barriers to adaptation

The majority of the farmers (61%) indicated that they had (knowingly) adapted to climate change, and these results concur with those of Apata (2011), in a study of farmers in Nigeria, who observed that 62% of the farmers had adapted and 38% had not adapted. These adaptation percentages were analysed further using the data on the adaptation measures used, and the results indicated that only 3.6% of farmers did not adapt at the household level, and 12.6 % did not adapt at livestock farming level. These results indicate that there was poor awareness of the meaning of adaptation; whereas the farmers were actually engaged consciously or sub-consciously in climate change adaptation. From these results it is evident that 25-34% of the farmers "unknowingly" adapted their household or livestock farming activities.

The main significant barriers for adaptation were the lack of information, lack of awareness, and lack of know-how. The lack of financial resources was not significant. This findings are in part similar to those of Maponya and Mpandeli (2013), and partially similar to those put forward by Ifejika-Speranza *et al*. (2010) and Kichamu *et al*. (2018). In the study by Maponya and Mpandeli (2013), barriers to climate change adaptation included: lack of information, lack of education and skill, and lack of government support. While Ifejika-Speranza *et al*. (2010) noted that for successful climate change adaptation, it was crucial to address the constraints amongst vulnerability and poverty because knowledge of climate change alone was not sufficient to generate significant adaptations by the farmers. Therefore, in this study, even though lack of financial resources for adaptation was not significant because the farmers lack knowledge, any future policy options, needs to address issues related to this constraint.

6.7.1.2 Approaches and strategies employed by farmers to adapt to climate change

The results indicated that the farmers use a range of adaptation approaches or measures to adapt their livelihood activities to climate change impacts. At the household level the main adaptations measures in terms of usage were: water harvesting and storage, varying planting dates for crops, selling livestock, changing the crop varieties – to drought tolerant ones, diversifying crops planted, and using agricultural extension services. Other adaptation practices included: seeking for employment, using technology, relying on remittances, and doing nothing. Whereas for livestock farming, the five main adaptations measures included: provision of medicines and pesticides, selling livestock, water harvesting and provision, seeking training, and engaging in mixed crop systems. The bottom five adaptations measures included: using insurance, borrowing funds, doing nothing, loaning out livestock, and relying on government food aid supplements for livestock. Other adaptation practices used included: seeking for employment, restocking, using forecasts, diversifying livestock, changing livestock breeds, and supplementary feeding. From these results, it was evident that the farmers use an assortment of actions and approaches to adapt their activities to climate change impacts. For household adaptation these outcomes correspond to those of other researchers such as Borokini *et al.* (2014) who reported that, in Oyo State, Nigeria, farmers' adaptation strategies included: planting new varieties, practicing mixed farming and multiple cropping. While for livestock farming, similar findings were made by scholars such as Silvestri *et al*. (2012) and Comoé and Siegrist (2015) with regard to mixing crop and livestock production, and destocking (selling livestock), but contrasting with regard to diversifying, supplementing livestock feed, and changing animal breeds where in Kenya these were top adaptation choices. Furthermore, matching conclusions were made by Kichamu *et al.* (2018) who concluded that in dry year periods, farmers cull animals, grow drought resistant crop strains, work on non-farming income generating activities, vaccinate their livestock, and also engage in farming goats and poultry to reduce their susceptibility to climate change risks. Additionally Habte *et al.* (2022) observed that in south-eastern Ethiopia, some of the adaptation options included culling animals or destocking, harvesting and storing hay and shifting to browsers instead of grazers. The only difference with the study results was that the farmers temporary migrated their livestock in Ethiopia to places with better forage. Given the diverse strategies to adapt to climate change used by farmers, Idrissou *et al.* (2020a) grouped these into four main strategies namely livestock production adjustment strategies, activity diversification strategies, livestock management strategies, and livestock selection strategies. From these results, it was apparent that climate change adaptation cannot use a “one shoe fits all strategy”, but it needs to consider a facet of strategies. This observation resembles a study by Below *et al*. (2010) on climate change adaptation in African agriculture which recognized that farmers used about 104 different adaptation activities.

The broad adaptation approaches or measures used by the farmers were grouped into three strategies, namely: technological, behavioural and managerial as outlined by Silvestri *et al*. (2012). The results of this categorisation realised the eight different strategies which are employed by the farmers for climate change adaptation at either the household level or for livestock farming. The main adaptation strategies by used at the household level included: a strategy combining behavioural, managerial and technological strategies which was used by 61% of the respondents; followed by a strategy combining behavioural and managerial strategies; then by that combining managerial and technological strategies. For livestock farming, the dominantly used strategy was that which mixed managerial and technological strategies used by 41% of the respondents; trailed by managerial strategies (15%), and a mix of strategies combining behavioural, managerial and technological strategies (15%). The results of farmers using combined adaptations strategies was also observed by Makate *et al*. (2019) while studying smallholder farmers in southern African. These were shadowed by the farmers doing nothing (13%). The number of these farmers who did nothing is significantly less than the outcomes of the study by Silvestri *et al*. (2012), who observed that between 28% and 89% of farmers in semi-arid and arid regions respectively, reported to have done nothing. The main reason for doing nothing is most farmers might not be aware of how to adapt, or they deliberately do not adapt; for example, some cattle farmers are reluctant to cull their livestock even during severe drought.

6.7.1.3 Discussion the predictors or determinants of adaptation

The MNL regression results indicated that 8 out of 13 explanatory variables were predictors of climate change adaptation at the household level, and these included: years keeping livestock, constituency, gender, household size, types of crops farmed, access to climate information, who the farm manager is, cattle ownership, and ownership goats or sheep. The variables that were found to enhance (positively predict) climate change adaptation at the household level were the following: years keeping livestock (experience), constituency (location), gender (males), the household head owning cattle, and household size. Whereas the variables that decrease (negatively predicted) the likelihood of the respondents adopting certain climate change adaptation strategies at the household level are: who the farm manager is (either the head of household or a non-family member), the types of crops farmed where farmers practised multi-cropping. However, ownership of goats or sheep predicted the adoption of climate change adaptation strategies either positively or negatively, depending on the strategy. For example, it was a positive predictor for the strategy "technological approaches" and a negative predictor for strategies "combining either behavioural and management or behavioural, management, and technology".

The results for climate change adaptation for livestock farming indicated that 9 out of 15 explanatory variables significantly predicted the probability of adaptation using the various strategies employed by the farmers. These significant predictor variables were: years keeping livestock, livestock farming expenses, occupation, constituency, gender, climate change knowledge, types of crops farmed, who the farm manage is, and goats or sheep ownership. The variables that positively predict climate change adaptation were: years keeping livestock, livestock farming expenses, occupation, constituency, gender-male, climate change knowledge, types of crops farmed, who the farm manager is, and goats or sheep ownership. Only two variables negatively predicted the likelihood of the farmers adopting certain climate change adaptation strategies for their livestock farming, and these were: knowledge of climate change and farmers practising multi-cropping.

From both the predictor variables used for climate change adaptation at the household level and the farming level there were common predictor variables, namely: years keeping livestock, constituency, gender, types of crops farmed, access to climate information, who is the farm manager and goats or sheep ownership.

The predictor, "years keeping livestock" essentially means experience, and such experience in livestock keeping has a positive correlation with climate change adaptation, the reason being farmers' knowledge of livestock farming increases with years. Similar findings were made by Maddison (2006), Nhemachena and Hassan (2007), Deressa *et al*. (2009), Idrissou *et al*. (2020b) and Tesfaye and Nayak (2022) who indicated that farming experience raises the likelihood of using efforts to adapt to climate change. In this light, it is evident that strategies to increase adaptation need to focus on increasing the farmers' experience. This can be accomplished through training and capacity build.

Experienced farmers with agricultural assets tend to integrate other farming with livestock (
For the predictor variable, "gender", the outcomes showed that male-headed households are most likely to adapt to climate change mainly because they are most likely to obtain information on the

latest technologies, and have rights to use land owing to cultural and societal barriers that limit females' use of land and other resources. These findings are similar to those of Deressa *et al*. (2009); Apata (2011), Deressa *et al.* (2011), Moroda *et al.* (2018); Makate *et al*. (2019) and Tesfaye and Nayak (2022), but conflict those of Nhemachena and Hassan (2007) and Mamba (2016) who found that female-headed households were most likely to use climate change adaptation methods. Therefore, gender can impact on adaptation, and thus, measures to enhance adaptation need to address the problems and disparities between males and females.

In this study, household size was a positive predictor of climate change adaptation. In fact, in most farming communities, larger families are generally associated with a higher labour force and ability to generate income, and this positively influences the probability towards climate change adaptation because they have less labour shortages. The conclusions of this study resemble those of Deressa *et al.* (2009), Deressa *et al.* (2011), Belay *et al.(* 2017), Snaibi *et al.* (2021), Adeagbo *et al.* (2021), Musafiri *et al*. (2022) and Tesfaye and Nayak (2022) who found that family size significantly and positively influences the likelihood of the adoption of climate change adaptations strategies.

The ownership of livestock either cattle, goats or sheep positively predicted climate change adaptation. In Eswatini livestock ownership plays a very important role of serving as storage of value or assets. Locally, the ownership of livestock, especially cattle, is actually called "the Swazis' Bank"; thus, their ownership increases climate change adaptation. This could result in that the farmers would go to lengths to protect their wealth, and thus, are more inclined to adapt. Similar finding were made by scholars such as Deressa *et al*. (2009) Ifejika-Speranza (2010) and Kuivanen *et al.* (2015) who noted that livestock ownership increase adaptation to climate change because the ownership of livestock, is associated with financial well-being or extra resources, Makate *et al*. (2019) also noted that adaptation is explained by access to resources. This financial well-being status also assists the farmers' access information which could assist in climate change adaptation.

Access to climate change information in this study is a positive predictor of farmers adopting adaptation strategies. Farmers with access to weather or climate information are well equipped for making more informed choices on climate change adaptation. These findings are similar to those of scholars such as Hassan and Nhemachena (2008), Belay *et al.* (2017), Moroda *et al.* (2018), Musafiri *et al*. (2022) and Tesfaye and Nayak (2022). Therefore, strategies to increase adaptation of farmers need to address issues of access to reliable sources of climate and weather information.

Furthermore, training of the farmers on how to use this information can improve their adaptation strategies towards climate change.

Location or (constituency) was also a positive predictor variable for climate change adaptation. This is because some locations are more exposed to climate change and different climate stimuli which could influence farmers' climate change perceptions, and also influence their adaptation choices. Similar findings were made in studies by Deressa *et al.* (2009), Deressa *et al.* (2011), Below *et al.* (2012), Moroda *et al.* (2018), Corbeels *et al.* (2020) and Adeagbo *et al.* (2021). To ensure uptake of climate adaptation, site or location specific adaptations need to be encouraged in line with local climatic conditions. For example, in the southern part of the Lowveld of Eswatini temperatures have increased, while in the northern part they have decreased and rainfall season has changed; while in the southern part it is has not. So, climate adaptation interventions cannot be the same.

In this study, expenses paid for livestock farming had a positive influence on adaptation. So, an increase in expenses essentially correlates with an increase in adaptation. Given that the more the farmers spend on their livestock is actually a proxy of the amount they use for adapting their livestock farms to climate change; furthermore, the amount spent is a function of income where in other studies farm income and livestock ownership represent wealth, and farmers are willing to invest more in the adoption of agricultural technologies (Belay *et al*., 2017; Ado, 2019). A similar finding was made by Deressa *et al*. (2009) and Silvestri *et al*. (2012) who observed that high income farmers took more risks, had better access to information, used long term planning, and are most likely to adapt to climate change. Similar findings were noted by Snaibi *et al*. (2021) in a study on pastoralists adaptation to climate change in Morocco where they observed that adaptation was affected by the wealth categories of the farmers where wealthier farmers adopted a greater range of approaches, while poorer pastoralists used less diverse adaptation strategies. Therefore, strategies that increase on farm income generation are more likely stimulate climate change adaptation.

The results indicated that the variable "multi-cropping" was a negative predictor of the respondents adopting a certain climate change adaptation strategy. The reason for this could be that multi-cropping is actually an adaptation approach, and thus, farmers using this approach are less likely to adapt their crop farming because they are already adapting. Furthermore, they are less likely to endure the impact of climate change on their crops because they have adapted. These results for practising multi-cropping are opposite to the findings of Borokini *et al.* (2014).

Correspondingly, knowledge of climate change was a negative predictor of the likelihood of the farmers adopting certain climate change adaptation strategies. This finding is, however, contrary to other studies and this particular study where access to climate information, which is a form of knowledge, is a positive predictor of farmers adopting certain climate change adaptation strategies. A study of farmers' perceptions to climate change by Habtemariam *et al.* (2016) provides some insight to this result by stating that farmers with understanding of climate change have substantially different perceptions than other farmers, mainly because their most recent experience of farm production shocks could influence them to negatively link climate change. Given that knowledge about climate change is key in implementing successful adaptation strategies, understanding this result might assist in enabling farmers to adapt. Thus, as a way forward it is suggested that this predictor needs more detailed research to ensure it does not impact on the adoption of adaptation strategies.

6.8 Farmers knowledge of climate forecasts and their use in adaptation

According to Wilk *et al*. (2017), seasonal climatological forecasts have become an essential part of early warning mechanisms to reduce farmers' drought risks, and also to enable adaptation to climate change (Klopper *et al.,* 2006; Dorling, 2014). The results indicated that 78% of the farmers indicated they had access to climate change information which in most cases relates to climatic data or forecast data, and 76% of the farmers indicated they had access to climate change information relevant to livestock farming. Given that access to climate information is key in adaptation and 61% of the farmers knowingly adapted to climate change, farmers' access to relevant climate information is key for them adapting their activities.

For the type of climate change information received by the farmers, the results indicated that the farmers received both weather and climate information as either, short term, medium term, or long term forecasts. With regards to weather information, 49% of the farmers received short term (day – week) information, 42% received medium term (week – month) information, and 9% long term (month – season/year) information. For weather information in relation to temperature, 70% of the farmers reported that they received short term information; 28% received medium term information; and 2% received long term information. With regards to rainfall information, 40% of the farmers reported that they received short term information; 55% received medium term information; and 5% received long term information. Lastly, for climate information, 32% of the farmers reported that they received short term information; 43 % received medium term information; and 25% received long term information. The main source of information was the radio, followed by the television. These findings are similar to those of Vogel and O'Brien (2006); Diouf *et al.* (2019) who noted that, in many studies, the preferred channels for receiving climate information was the radio.

From these results, it is evident that farmers are relatively aware of the different climate forecasts based on how they were able to unpack them into different components; for example, temperature, rainfall, weather, and climate. However, from these results, it is also evident for all types of weather and climate variables that over 75% of the farmers are receiving information that is either daily, weekly, or monthly forecast which cannot be really used in decision making, such as planned adaptation. This observation is similar to that of Jones *et al.* (2000) who state that an adaptation prerequisite for agricultural production is having access to timely and accurate climate information about three to six months ahead of schedule.

Based on the farmers' knowledge of seasonal climate forecasts and projections, the results from the key informants' interviews indicated that they were all aware and knowledgeable of seasonal climate forecasts. They indicated that most of the information received from these forecasts was skewed towards dry land crop farming. Such forecasts informed them of the onset of rains and the climatic outlook, and with the recommendations of the crops to grow. These forecasts were less focused on livestock farming, and in most cases, when used, advice either came too late. With regards to long term climate projections, the results indicated that the farmers' were less knowledgeable about long term projection. These results further indicated that seasonal climatic forecasts with agronomic advice are provided for crop farming to ensure that adaptation decisions can be made for crop farming, but for livestock farming this advisory service is not provided. This observation is similar to that of Archer *et al.* (2021) who state that to increase usefulness of climate forecast information, local relevance of what matters to farmers must be addressed such that it supports their understanding of their farming systems and how this system might be impacted by climatic elements. A World Bank (2016) report further notes that the climate forecasts must be accompanied by meaningful agronomic advice for them to offset the doubts that restrict farmers' deciding against climate risks. As is the case with livestock farmers in the Lowveld of Eswatini, meaningful advice is lacking; thus, they cannot utilise the seasonal forecasts they receive to their full potential for livestock farming mainly because these have been designed for dry land crop farming. There is no accompanying advice for livestock farmers as is the case with the agronomic advice for crop farming.

6.8.1.1 *Farmers awareness and use of climate information for livestock farming*

With regards to the awareness and use of the weather or climate forecast information for certain livestock farming activities by the farmers, the results indicated that the farmers showed an awareness of use of climate information (ranging between 57% and 91%) for different activities. Furthermore, a number of farmers who are not sure how to use weather or climate forecasts ranged from 8% to 28% per livestock farming activity, while farmers who did not use or disagreed with the use of weather or climate forecast ranged from 1% to 15% per livestock farming activity.

From these results, it was evident that the awareness and use of weather or climate forecast information varied per farming activity, but the use or awareness was higher for short term adaptation activities such as supplementary feed for the livestock, provide disease and pest management solutions, or culling of the livestock. However, it was less used for long term adaptation activities like planned calving and restocking of livestock. From this observation it is clear that most the farmers make use or know that weather and climate forecasts can be used as tools to mitigate the impacts of climate variability or change. Secondly, the awareness and use of climate forecasts as a tool has not achieved its full potential given that there is still high uncertainty (up to 43%) for some activities. Therefore, farmers still need to be capacitated on how to use climate forecasts for their livestock farming with the aim of climate proofing their livestock farming activities. The results also indicated that the farmers used forecasts more during times of drought. A comparable conclusion was made by Archer *et al.* (2021) who concluded that farmers who had access to weather forecasts generally made use or referred to the forecasts when there was mention of drought such as the El Niño phenomenon.

6.8.1.2 *Farmers use of seasonal forecasts*

In connection with the use of seasonal climate forecasts, the results indicated that seasonal climate forecasts are used especially for dry land crop farming. While seasonal forecasts are not or less used for livestock farming, because these forecasts lack the accompanying advice for livestock farmers. They are not timely and sometimes unreliable. However, when seasonal forecasts are available and are received timely, the farmers use them to plan their adaptation activities such as to cull and also to plan for supplementary feeding for periods when grass is limited. These results resemble those of Archer *et al.* (2021) who noted that tailored forecasting to support the livestock sector in South Africa and in the region remains, however, an area of limited focus, but of much discussion during the 2015/6/7 El Niño. Correspondingly, these results are similar to those of an earlier study by Manatsa *et al.* (2012) from Zimbabwe where the use of the seasonal rainfall forecasts was very low, mainly due to “poor forecasts” and inadequate lead times in the forecasts;

Whilst Rasmussen *et al.* (2014) found that livestock farmers used the seasonal forecasts data to fine-tune their crop farming activities instead of supporting livestock farming, because these forecasts were tailored for crops. Therefore, for farmers to use the forecast for livestock farming adaptation, additional information relating to the date of onset of rains, flooding incidents, and grazing availability is needed. Such information would be used to by the farmers to make decisions with regard to herd composition and to inform the purchase of supplementary fodder (Rasmussen *et al*., 2014).

6.8.1.3 Adaptations based on seasonal climate forecasts and projections

The results indicated that the key informants used several varied strategies for climate change adaptation, and some proactive approaches included: diversifying livestock, diversifying their crops, the use or seasonal climate forecasts and associated advice for their crop farming. While some culled and sold livestock before the winter, to seeking employment. While reactive approaches included supplementary feeding during food shortages, providing water for stock watering, and culling.

When the latest winter seasonal forecasts were shared with the farmers, their reactions to adaptation included lack of trust in the projections. Other adaptation strategies considered were: they would cull/sell unproductive animals to reduce the burden for supplementary feeding; they also planned for the provision of supplementary feeding, water, medicines, supplements and pesticides for their livestock. The farmers also halted other operations that required additional resources and focused on sustaining the existing livestock. These outcomes resemble those of Archer *et al.* (2021) in a study in South Africa on climate risks and tailored forecast products, where they asked farmers to illustrate how they might use a tailored seasonal forecast for the livestock section. The answer was, "*positive; indicating that if they had trust in such a product (for example, access to verification information); they would make clear use of it in grazing and land management operations (including provision of supplemental water, and changed rotational grazing, including access to higher carrying capacity rangeland – where available*" (Archer *et al.*, 2021, p. 5-6).

The results indicated that the farmers did not deviate from the normal adaptation approaches they use. It was, however, mentioned that planning for the adaptation was very important because all feeds, medicines, and culling could be arranged before the actual drought event. Similar findings were made by Archer *et al.* (2021) where they noted that proper or tailored seasonal forecasts can assist farmers in making informed decisions regarding scheduled grazing, veld burning, vaccination decisions, buying of livestock feed and supplements, stocking and destocking.

With reference to climate projections, the results from farmers in the northern part of the Lowveld of Eswatini indicated they might continue as usual because the climate might get wetter; while those in the south indicated that they are more likely to plant drought tolerant grain such as sorghum instead of maize, and invest in livestock watering such as rainwater harvesting or use of groundwater, and in more resilient livestock such as goats, which also browse on trees which are more resilient to drought.

Concerning practices to improve the use of climate forecasts for livestock farming, these need to involve training and capacity building of the farmers for them to understand and be in a better position to use these forecasts. Secondly, those producing the forecasts need to make sure that they are reliable, timely, and specific (both area and type of farming specific). Based on these findings it was apparent that the use of seasonal forecasts in agriculture was common for dry-land crop farming but less common for livestock farming; since in livestock farming the uses tend to be proactive; for example, planning for projected impact of a drought and implementing culling or funds to resources to cater for supplementary feeding.

In summary it is evident that climate forecasts are used at the household level, particularly for crop farming and the use for livestock farming is minimal. The main barriers to the use of seasonal forecasts as an adaptation tool for livestock farming are: lack of knowledge, lack of advice specific for livestock farming that accompanies the seasonal forecasts as opposed to advice for crop farming, the lack of timely forecasts, and issues relating to reliability of the forecasts. The results indicated that climate adaptation strategies used when the farmers receive information on climate forecasts on time do not change from the normal strategies they use; however, what was of note was that these timely forecasts give the farmers ample time to plan for the implementation of the adaptation strategies. Also noted was the need for training of how they could optimise the use of these forecasts.

6.9 Discussion climate change policy evaluation

The evaluation of the climate change adaptation policies relating to livestock farming made use of two approaches: the a top-down approach which made use of thematic and content analysis as well as a bottom-up approach which makes use of interviews with farmers within the sectors studied. The results of this evaluation indicted that Eswatini has an abundance of policies to facilitate climate change adaptation; however, the implementation of these policies is very questionable and disjointed because there is no legislation to operationalize it. Most if not all legislation precedes these policy documents. Furthermore, the adaptation at the farm level is not guided by a legislative framework. The reason for this is that most of these policies are developed in response to funding and support from the UNFCCC mainly to reduce social vulnerability to climate change. A similar observation was made by Yiran and Stringer (2017) from Ghana and England *et al.* (2018) who noted that most of the adaptation policies are prepared in line with international considerations such as its obligations under the UNFCCC, and these policies target the agriculture and water sectors which are highly vulnerable to climatic change. In light of these observations, significant gaps exist between policy documents and their actual implementation. Similar findings were made by Holler (2014) in a study in Tanzania where significant gaps existed between the policies and the realities of adaptation.

The results from the top-down approach which made use of thematic and content analysis, of a total nine (9) policy documents relevant to livestock farming which yielded ten thematic areas, and from these themes, 251 adaptation interventions were observed to be present in the documents. The thematic areas were prioritised from the most important using the content and thematic analysis and in terms of importance, these are: capacity building, training, awareness and information sharing, technology, research and development; development of relevant policies; rangeland and pasture management; livestock breeding, diversification and intensification and marketing; carrying capacity management and improvement; disease and parasites management; alternative livelihood and diversification; institutional development and strengthening, and water supply or livestock watering. These results are relatively similar to those of Muchuru and Nhamo (2017) who identified 95 adaptation interventions that were grouped into eight thematic areas while reviewing UNFCCC national communications reports.

The bottom-up approach interviewed and asked all livestock farmers to rank what strategies they deemed most appropriate to help them adapt their livestock farming to climate change. The results yielded the following strategies (ranked in terms of importance): the provision of livestock markets is the top priority; providing training and capacity building on all aspects related to livestock farming and climate adaptation; the provision of improved early warning systems (such as specific seasonal climate forecasts); the need for improved grazing (rangeland management) as most communal lands are overgrown with alien species and bush encroachment; having climate proofed livestock systems; assistance with access to livestock services infrastructure such fencing, dip tanks, and watering facilities, and breed diversification and drought relief provision.

Given that some of the farmers indicated that they had adapted their livestock to climate change while others had not, a Chi-squared association between the ranked adaptation strategies they wanted government to implement to assist adaptation, and the whether they had adapted or not was determined. The results indicated that there was a significant association for five strategies out of the eight. The results of the top-down and bottom-up approaches as well as the Chi-square test were combined and yielded two sets of results: a priority of adaptation options for all farmers (those who have or have not adapted), and a priority for farmers who have adapted. The top five priority to assist all farmers (both those who have not adapted and adapted) are: the provision of training and capacity building; assisting farmers with improved early warning systems; provision of livestock markets; improved rangeland and pasture management and climate proofed livestock farming; and drought relief provision

The top five policy options to be implemented to assist farmers who have adapted to further adapt or improve their adaptation in terms of rank from the most important are: training and capacity building; improved rangeland and pasture management and improved early warning systems; the development or implementation of policies on drought relief assistance, and livestock breed diversification

These outcomes resemble those of Urwin, and Jordan (2008) who noted that neither the Top-down or Bottom-up approach offered a complete picture of the different adaptation policies to be implemented, but a combination of the two approaches offers a new approach on climate policy integration. Therefore, these outcomes inform on climate policy implementation and integration to support change adaptation in the sector. On another note Kaijage (2012) made a similar finding on policy options to be used for adaptation and also indicated that there is no single best option for adaptation, but the integration of various adaptation options are a critical step to addressing the big picture of adaptation.

From these results proposed, policy guidelines to assist the farmers adapt need to include policies that will assist them with: training and capacity building on climate change and adaptation; improved rangeland and pasture management; improved early warning systems; marketing and livestock breed diversification. These policy guidelines will assist both farmers who have not adapted and those that have adapted to improve their adaptation. Such a policies need to be supported by a legislative framework, monitoring, and evaluation to ensure implementation.

6.9.1 Discussion on policy linkages with other research findings.

The outcomes of the evaluation of the climate change adaptation policies needs to be considered also in light of the other findings relating to farmers perceptions, adaptation approaches, the drivers of adaptation, the barriers to adaptation, the knowledge and use of seasonal climate forecasts because there are a number of synergies that must be considered when implementing the policy recommendations. These synergies need to start with the notion for adaptation to climate change to be possible, farmers should have correct perceptions so they can perhaps implement adaptation measures. The common themes in the predictors of farmers perception on climate change, the determinants of adaptation and those in the barriers of adaptation or use of climate forecasts for adaptation as well as those raised in the policy analysis were summarised in a tabular format and the results are in Table 6.1 below.

Table 6-1: Common themes in the perceptions, adaptation, adaptation barriers and policy evaluation

Common Themes	Perceptions	Adaptation	Barriers of adaptation or use of forecasts	Policy
Education, Training or Experience	Education -access to climate information	Experience, climate change knowledge	Lack of information lack of knowledge lack of awareness lack of know-how	Training and capacity building on climate change and adaptation Rangeland & pasture management
Financial (Assets, income, expenses or marketing)	Income from livestock	Expenses and ownership of cattle, livestock farming	The lack of financial	Marketing and livestock breed diversification
Age Gender household, farm manger	Age, gender, household size, Farm Manager	Gender household size, farm manager	Age and gender household size farm manager	
Spatial location specific	Location	Location	Lack of specific advice for livestock	Improved early warning systems

From the themes identified and the associated synergies it is evident that for adaptation to take place the farmer has to be experienced and without experience of what they dealing with, training and capacity building is a must. This was evident as most of the farmers identified lack of knowledge, awareness and knowhow as barriers to adaptation and use of seasonal forecast for adaptation. Even farmers perceptions are linked to education. Thus educating the farmers on climate change and its adaptation is key moving forward. Secondly, the farmers need to be financially sound for them to adapt, hence the need for proper marketing of livestock. Thirdly age, gender, who manages the farm and the size of household are all factors that influence perception, adaptation and even the barriers for adaptation. Therefore any intervention needs to focus on these different groups for example different age groups, gender, farm managers and different households size to assist with climate change adaptation and thus policy implementation must focus on each groups individual requirement. Lastly all policy interventions need to be site specific, spatial location is key even for policy interventions because spatially the farmers' needs and experiences are different.

These results actually concur with the findings of Eisenstein (2020), while studying natural solutions for intensifying production to tackle food security and environmental crises, where he reports that researchers need to design intervention programmes that must be compatible with local conditions to facilitate information transfer to the farmer. Whereas Maïga *et al*. (2020) states that such initiatives must also account for diversity in gender, educational status and age (youth) to raise sustainability in agriculture. Simpson *et al*. (2020) states that climate change knowledge incorporates being aware of both climate change and its causes, and thus strengthens informed adaptation reactions, accordingly education increases climate change literacy but poverty decreases it, gender was also found in several countries (Nigeria, South Africa and Tunisia) to impact on climate change literacy, with women having lower climate change literacy. While a study on the contributions of farmers' organizations to smallholder agriculture by Bizikova *et al*. (2020) reveals that gender and policy development should focus on improving the participation of women in farmer organisations and such an intervention could be accomplished by providing agricultural extension support aimed at building women farmers' capacities in areas such as technology uptake and marketing. Corbeels *et al*. (2020) emphasises that adoption or adaptation needs to be understood in the local context, for example in mixed copping systems in sub-Saharan Africa, conservation agriculture (mulching with crop residue) may not work because the famers use the residue as winter fodder for livestock.

6.10 Summary

The aim of the present chapter was to discuss the results in terms of the key study objectives. From the discussion of results it was evident that the climate of the Lowveld of Eswatini had changed, and the farmers had strong perceptions that temperatures had increased, and rainfall decreased. These views were not fully supported by empirical evidence. The farmers reported both impacts of climate change to their household and livestock farming and about 61% of them indicated that they had adapted their homes and livestock farms using a multitude of approaches. These strategies were then grouped into three main strategies, a combination which resulted in eight different adaptation strategies. The modelling results indicated that there were a number of predictor variables that determine perception, together with the impact and adaptation options used by the farmers. With regard to use of climate forecasts for adaptation, they are mainly used for crop farming; and their use in livestock farming is not widespread because the climate forecasts and information is not tailor-made for it. Further, more access to climate forecast does not alter adaptation options used by the farmers, but only helps the farmers to plan for adaptation. For future use of seasonal forecasts as a tool for adaptation, training and capacity building on how to use these forecasts is required. Lastly, the policy evaluation highlighted that the country has an abundance of policy documents on livestock adaptation; however, they were not operationalized for implementation due to lack of supporting legislation. Therefore, there is need for the enactment of laws and regulations to facilitate implementation. The key policy option to assist in adaptation is that on training and capacity building. Other policies to facilitate adaptation are improved rangeland and pasture management; improved early warning systems; marketing and livestock breed diversification.

CHAPTER 7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

Presented in this section is a summary of the study outcomes, the conclusions, and the recommendations. The main aim of this study was to investigate the impacts of climate change on livestock farming together with determining the adaptation options currently used, and determining if access to climate forecasts or projections influences the farmers' climate change adaptation strategies. The major reason for studying such was to enable understanding of climate change on livestock farming in the Lowveld of Eswatini, and to propose and inform future policies that could assist in developing a climate-proofed livestock industry in the study area. This aim was to be achieved by answering the following research questions:

a. How is livestock farming in the Lowveld of Eswatini affected by climate change?
b. What are climate change adaptation measures utilised by livestock farmers?
c. How does the knowledge of, and availability of access to future climate forecasts and projections influence farmers climate change adaptation strategies?
d. What are proposed policy guidelines which could assist livestock farmers adapt to climate change?

The outcomes to these questions are summarised below.

7.2 Summary of study findings

For the purpose of answering the research questions, an in-depth survey of relevant literature on each question was conducted and discussed in the literature review. Furthermore, different methodologies for answering the questions were also considered, and the most relevant for this study was chosen which was a mixed-methods approach that collected and used both quantitative and qualitative data. Primary data was collected utilising a structured questionnaire and an interview guide for the key informant interviews. These key informants consisted of community leaders who were active farmers –that were used to obtain data, or replacing the FGDs, because of COVID-19 restrictions on gatherings. Secondary data consisted of meteorological data, for the Lowveld of Eswatini covering a period of 31 years, seasonal forecasts, and climate projections. A total of 278 households were successfully surveyed and seven key informant interviews were conducted with farmers from seven different constituencies. The data was analysed employing both quantitative and qualitative methods. The quantitative analysis utilised an assortment of either descriptive or inferential statistics. A summary of the findings is as follows.

The majority of the livestock farmers (respondents) were: old males (above 50 years), were married; lived in household with less than ten persons, had at least primary education, and mainly grew grain crops. The dominant livestock reared by most farmers were cattle, goats, and chickens. Other livestock reared were sheep, pigs and donkeys. The average head size for cattle, goats, and sheep was about 30, while about 90 % of the cattle farmers and 50% of goat farmers lost their animals to drought or climate change, with average losses ranging from 10 cows or 6 goats per farmer. This socio-biographic information of the farmers was used as independent variables in most of the (statistical analysis) modelling.

The climate trends of the Lowveld of Eswatini were determined using 31 years (1988-2018) of temperature and rainfall data from two weather stations, namely: Mhlume (in the northern part of the Lowveld), and Big Bend (in the southern part of the Lowveld). A third station, Sithobela (in the central part of the Lowveld) only had a rainfall record. The data was analysed for trends using M-K test and Sens' slope. The key results indicated that there is a significant change in the climate of the Lowveld, particularly in the northern part, mean and maximum temperatures decreased (by 0.5 ^{o}C and 1.1 ^{o}C respectively) on an annual seasonal and monthly time-scale, while for minimum temperatures there was no change except for June temperatures that increased. In the southern part, mean, maximum and minimum annual temperatures increased by about 1 ^{o}C; while mean, maximum and minimum winter temperatures increased by above 1.1 ^{o}C. Also, the minimum autumn temperatures increased by 1.5 ^{o}C. With regards to rainfall, a significant decline was seen for the summer rainfall and for the months of December and February in the northern part, with no significant change for annual rainfall. Similarly, there were no substantive changes in the annual rainfall for the southern part and the central part; however, there were significant variations in monthly rainfall for the southern part, where the June rainfall had significantly decreased, while in the central part the June and October rainfall also significantly declined.

The majority (over two thirds) of the farmers indicated they had knowledge on climate change, and had access to climate change information appropriate for livestock farming; most of which was sourced from the radio, television or family and neighbours. The farmers' knowledge of climate change was significantly determined by age, education, household size, and income from livestock sales.

The farmers were questioned on their perceptions of the Lowveld climate, and they acknowledged that climate has changed. To be specific, temperatures had increased, rainfall had decreased, rain season had changed (become shorter), droughts and drought frequency had increased, and winds had increased. When the farmers' perception of temperature, rainfall, and rain season was compared against the empirical data, there was correlation with temperature increase for the southern part, and a decrease or change in rain season. However, there was no correlation in the decrease in annual rainfall for the entire Lowveld of Eswatini or the increase in temperatures for the northern part. This variance between empirical data and perception has been observed in other studies, and the most probable cause of the variation is put forward by Debela *et al.* (2015) who state that the reasons for such perceptions could be actual localised change, enhanced climate variability, or climate extremes that can alter the farmers' perception. In this case, the severe drought and El Nino (2014-2016) could have altered the belief. Thus, the farmers' perceptions for temperature and rainfall significantly varied with location.

The majority of the farmers stated that they perceived that climate change had negatively impacted all household and livestock farming activities. The MNL regression was utilised to determine the predictors of the farmers' climate change perceptions, and most independent variables in the model were socio-biographic data on the farmers. The results indicate that for the perceptions for temperature, there was no significant predictor variable. For the farmers' perception of "an increase" or "a decrease" in rainfall their "age" and "location" were positive predictors of a perception of increase in rainfall, while there were no significant predictors for a decrease in rainfall. For the farmers' perceptions of change in rainfall season: education, and location were negative predictors; age was a positive predictor of an increase in rain season; while farmers' experience, age, the types of crops grown, who manages the farm, and location were all positive predictors of a "decrease in rain season". Whereas, location was a negative predictor of either "an increase" or "a decrease" in rainfall, for the farmers' perception of drought frequency. For the farmers' perceptions of wind: age, who manages the farm, and location were all negative predictors of an increase in winds, while household size was a positive predictor. The variables: "who manages the farm" and "location" were negative predictors of a decrease in winds.

For the impacts on the household, the farmers' perception was that climate change had adversely impacted their household, and for a positive impact of climate change on the household, the variable "employment status" was a negative predictor of this perception. Whereas for the negative impact perception: educational level, location (central part) employment status, farmers' main occupation, who manages the farm, the ownership of cattle, the ownership of goats and sheep, and if the farmer lost livestock to drought were all negative predictors of the negative perception, while "location" and "gender" were positive predictors of perception.

Again, for climate change impacts on livestock farming, the farmers' perception was that it adversely affected livestock farming. There were no predictors for a perception of a positive impact, but for the negative impact perception, education, gender, household size, access to climate information, and who manages the farm were all positive predicators of the negative impact perception; while "ownership of cattle" was a negative predictor of the perception of a negative impact on livestock farming.

The farmers' climate change perceptions are linked to how they adapt to it. Most farmers (61%) indicated that they adapted to it, and significant barriers to adaptation encountered by the farmers were: lack of information, lack of awareness, and lack of know-how. Therefore, to promote adaptation, assisting the farmers overcome the barriers is key.

The results indicated that the farmers use many different methods to adapt their household activities and livestock farming. The top five household adaptation approaches included: water harvesting and storage, varying planting dates for crops, selling livestock, changing the crop varieties to drought tolerant ones, and diversifying crops planted. For livestock farming, the adaptation measures by usage included: provision of medicines and pesticides, selling of livestock, water harvesting and provision, seeking training, and engaging in mixed-crop systems. The adaptation measures used by the farmers were grouped into three main strategies, namely: technological, behavioural and managerial as outlined by Silvestri *et al*. (2012). Thus, this categorisation realised eight different strategies that were used by the farmers for adaptation. The main one used at the household level was a strategy combining behavioural, managerial and technological measures which was used by 61% of the farmers; whereas for livestock farming, the dominantly used strategy was a combination of managerial and technological strategies used by 41% of the farmers.

The MNL regression analysis indicated that climate change adaptation at the household level, using these adaptation strategies, was significantly predicted by the variables: farming experience, location, gender, household size, types of crops farmed, access to climate information, who the farm manager is, cattle ownership, and goats or sheep ownership. Of these variables, those that enhance (positively predict) climate change adaptation are: farming experience, location, gender, and the household head owning cattle, goats or sheep ownership, and large household size. At the livestock farming level, significant climate change adaptation predictor variables were; farming experience, livestock farming expenses, occupation, location, gender, climate change knowledge, types of crops farmed, who the farm manager is, and goats or sheep ownership. The variables that positively predicted climate change adaptation were: farming experience, livestock farming expenses, occupation, location, gender, climate change knowledge, types of crops farmed, who the farm manager is, and goats or sheep ownership. Therefore, to enhance climate change adaptation in the Lowveld of Eswatini, factors and measures that enhance the positive predictors of adaptation need to be encouraged or implemented for both the household activities and livestock farming.

With regards to knowledge of, as well as, use of climate forecasts by the livestock farmers, the findings revealed that the farmers are knowledgeable about seasonal climate forecasts used for dry land crop farming and regarding their use in livestock farming, their knowledge is minimal mainly because specific seasonal forecasts targeting livestock farmers are not available. The main barriers to the use of seasonal forecasts as an adaptation tool for livestock farming are: the farmers' lack of knowledge, the lack of advice specific for livestock farming that accompanies the seasonal forecasts as opposed to advice for crop farming, the lack of timely forecasts, and issues relating to reliability of the forecasts. With regard to how farmers adapt or plan to adapt to information on future seasonal forecasts, the results revealed that the farmers do not alter their normal adaptation strategies they use; but they use the information from the forecasts to plan their adaptation strategies. The major challenges raised by the farmers regarding the use of seasonal forecasts for livestock farming was that, there was need for actual livestock specific forecasts and for training on how they could optimise the use of these forecasts.

The policy evaluation indicated that the country had an abundance of policy documents on livestock adaptation to climate change; however, they were not operationalized for implementation. There was need for the enactment of laws and regulations to facilitate implementation. A number of suggested policy interventions were put forward by farmers, and these were combined with those from the policy documents, and then ranked based on priority. The top three adaptation options to be considered for policy implementation for all farmers (both farmers who adapted and those who did not) are: the provision of training and capacity building; assisting farmers with improved early warning systems; and the provision of livestock markets. For the farmers who have adapted their livestock farming, the top five adaptation options to enhance adaptation are: training and capacity building, improved rangeland and pasture management, improved early warning systems, the development or implementation of policies on drought relief assistance, and livestock breed diversification.

Outlined below are the major conclusions drawn from the study findings.

7.3 Study Conclusion

From the empirical evidence, the climate of the Lowveld of Eswatini has significantly changed in the past 31 years. Temperatures have increased, in the southern part in line with what is happening in Southern Africa. In the northern part; however, the temperatures have decreased, and this is the opposite of the finding of most other studies. Annual rainfall has high variability but no significant changes occurred; however, significant changes occurred for a change in rainfall season or monthly rainfall.

The livestock farmers in the Lowveld of Eswatini practise mixed-farming, where they combine raising livestock with growing crops. Livestock farming is dominated by males who are old, and where there are female farmers, the majority are widows. This is because livestock is reared in a household set-up which is dominated by males. While most of the farmers have at least some form of primary education, the majority of these farmers rear cattle, goats and chicken as livestock, and most of these farmers have lost livestock to drought.

The livestock farmers' climate change perceptions are that the climate has significantly changed over the last 20 – 30 years, and evidence of this change includes: increased temperatures, decreased rainfall, delayed rain season, increased winds, and greater incidence and intensity of drought. When the empirical temperature and rainfall data was compared to these perceptions, there was disjointed correlation; for example, in the northern part of the Lowveld, temperature trends decreased, and the summer rainfall has also decreased; whereas in the southern part temperatures have increased with an exception of only a few monthly temperatures that have decreased. It is likely that the disjointed correlation between empirical trends and the farmers' perceptions was modified by extreme events, especially the recent El Nino (2014-16). This is because extreme events are known to alter the respondents' perceptions about climate.

It was evident from the study that most of the farmers were knowledgeable about climate change, and were able to access climate change information. The major sources of this information were the radio and television. Furthermore, contrary to what was expected, formal extension services were not the main source of information on climate change to the farmers. Given that such services are supposed to be the credible source of technical information on farming to the farmers, there seems to be a fragmented source of information; hence, efforts to join these sources might assist in addressing credibility of information issues. In addition, since most farmers access information through such sources, information sharing and training initiatives on climate change adaptation should consider using these information sharing platforms.

Most farmers, in this study, viewed climate change as having negative impacts on their household and livestock farming endeavours. They had varying perceptions towards it and how it impacted on their household or farming activities. Of particular note was that farmers' perceptions were spatially different by location.

The MNL regression indicated that the common predictor variables of the farmers' perceptions towards climate change indicator variables, namely: rainfall, drought frequency, rainfall season, and wind were the farmers' age, the location, and who managed the farm. There was no significant predictor variable for temperature, and this is likely because over 99.3% of the farmers stated that temperatures had risen. Furthermore, the MNL regression revealed common predictor variables of climate change impact on household and livestock farming activities, and these were: educational level, location, the ownership of cattle, and who managed the farm. The literature provided has proven that farmers' perceptions of climate change influences adaptation; thus, interventions to increase adaptation need to focus on farmers' perceptions of climate, and how it has changed. This can be done by focusing on the common predictor variables which enable better perceptions of the climate and its impacts. Moreover, enhancing the farmers' perceptions or climate change knowledge and its associated risks helps the farmers to be prepared for its impacts and ultimately how to adapt to such impacts, if they are negative, or how to take advantage of the impacts if they are positive.

The approaches employed by the farmers to adapt to climate change are many, and also vary with location, and amongst the farmers. For better comparison and understanding, these different approaches were grouped into three categories, namely: technological, behavioural and managerial in line with categorisation by similar studies. This categorisation yielded a combination of eight different strategies for adaptation. The dominant strategy used by the respondents for household adaptation included strategies combining behavioural, managerial and technological approaches, and was used by 61% of the farmers. For livestock farming, the dominant adaptation strategy was a combination of managerial and technological strategies used by 41% of the farmers. From these strategies it is evident that for household adaptation, a combination of three strategies are used by a great majority of the farmers, while for livestock farming the dominant strategy is mainly a combination of technology and managerial strategies. Based on these results, it is evident that behavioural strategies for climate adaptation are less used for livestock farming adaptation; therefore, there is need to improve the farmers' use of behavioural strategies. The MNL regression indicated that positive predictor variables that affect the farmers' selection of adaptation strategies at the household level included: farming experience, location, gender, household size, ownership of cattle, and goats or sheep, whereas farming experience, livestock farming expenses, occupation, location, gender, climate change knowledge, types of crops farmed, who managed the farm, and goats or sheep ownership are positive predictors of adaptation for livestock farming. These imply that if farmers' choices of adaptation are influenced by these variables, optimisation or improvement in adaptation or strategies to improve the farmers' adaptive capacity need to be focused on these variables.

The significant barriers to adaptation amongst the farmers were the lack of awareness, lack of information on climate change adaptation, and lack of know-how. From these it is evident that to increase climate change adaptation, the farmers must be capacitated to increase their awareness and be provided with relevant climate information. This will address the barriers to the farmers' adaptive capacity and will likely result in raised climate change adaptation and resilience.

The study indicated that the livestock farmers are knowledgeable of seasonal climate forecasts and their use in farming as an adaptation tool, and most farmers rely on such seasonal forecasts for adaptation of crop farming. The reason is seasonal climate forecasts and associated extension advice is packaged for crop farming and not for livestock farming. There is, therefore, a dire need for seasonal forecasts that are meant for livestock farming, and to be issued on time to allow the farmers to plan their adaptation. Farmers' access to future seasonal forecasts and projections does not alter the adaptation strategies they use to adapt, but assist the farmers to plan for future adaptation. Proper planning for any adaptation intervention was key for the farmers and resulted in less losses.

From this study it was evident that Eswatini has an abundance of policy documents on livestock adaptation to climate change; however, they were not operationalized for implementation as in most cases these documents are preceded by legislation. From a farmers' perspective a number of policy options for implementation were mentioned, and their prioritised policy options were not in line with the prioritised policy options by government, necessitating the formulation of an aligned policy prioritisation, resulting in a policy implementation that focuses on training and capacity building; assisting farmers with improved early warning systems, the provision of livestock markets, or improved rangeland and pasture management.

7.4 Limitations of the Study

The study has a variety of limitations and these are:

a. The study was to evaluate the climate change impacts on livestock in the Lowveld of Eswatini. It focused mainly on small and medium scale individual farmers, but did not evaluate the impact on large scale ranchers (the ranches are operated by large scale companies on vast areas of land). The main reason for excluding these ranchers is that a different methodology would have been required to study such entities because they are not similar to the individual farmer, and the climate change impacts on these could also be different. A comparison of the strategies used for adaptation can form the basis of future studies.

b. The other limitation of the study was that the FGDs could not be used to gather data on the use of seasonal forecasts due to the restrictions on gatherings imposed throughout the country due to COVID-19. The data on these was gathered using key informants – who were livestock farmers with leadership roles in the community. A very similar approach of using key informants due to gathering restrictions was used by Archer *et al.* (2021) when gathering data on the utilisation of seasonal forecast on livestock farmers in South Africa. Therefore, future studies evaluating how excess to seasonal forecasts influences farmers adaptation can consider FGDs and participatory approaches.

c. Another limitation of the study was that there are limited meteorological measuring stations within the study area, and generalisations regarding climatic information had to be made using this limited information. Future research should consider incorporating these stations with remote-sensed data to enable increased comprehension of the farmers' perceptions and adaptations in relation to observed climate trends.

Despite the above mentioned limitations, the study was able to answer the research questions and fulfil its purpose.

7.5 Recommendations to enhance adaptation

In light of the study outcomes, the following recommendations to enhance the farmers' climate change adaptation strategies are put forward:

There need for holistic capacity building on climate change

The study showed that 39% of farmers indicated that they did not adapt to climate change mainly because they had little or no knowledge about climate change, its impacts, and how to adapt. Therefore, this lack of knowledge negates adaptation and places the farmers at risk of climate change; hence, the following recommendations:

- that a coordinated and comprehensive training and capacity building programme on all aspects of climate change be provided to the farmers.
- that the Ministry of Agriculture and Cooperatives would coordinate such training with other key stakeholders who have a role in livestock farming.

To use an inclusive approach for climate change adaptation policy development

In the review and prioritisation of policies for climate change adaptation, it became evident that most of the policies were developed using a top-down approach. There is need to incorporate both the top-down and bottom-up approaches in the development and review of existing policies. This approach would enable effective implementation because the process of policy development assists in awareness creation and fostering ownership or acceptance by the farmers of the adaptation policies.

There is need for development of research-policy linkages.

All adaptation policies should be informed by research. Climate change impacts and adaptation policies must be influenced by empirical data gathered through research, and similarly the need of the policy must be informed by research. This will ensure policies are better thought out and more effective.

There is need for strengthening communication

The access to, and use of seasonal forecasts findings highlighted the need for an improved communication of climate information. It is recommended that communication channels between the farmers, extension services, meteorological services, politicians and disaster management agencies be created and maintained for information sharing on climate change. This will ensure that the constraints to information flow are minimised.

The use of predictor variables for the implementation of adaptation strategies.

The study findings indicated that there were a number of significant positive predictor variables such as: farming experience, livestock farming expenses, occupation, location, gender, climate change knowledge, types of crops farmed, who the farm manager is, and goats or sheep ownership played a key role in determining how the livestock farmers adapt. Therefore, any intervention to assist the farmers with climate change adaptation should consider these variables.

7.6 Recommendations for future research

In light of the outcomes of the study the following topics are recommended for future research on climate change and livestock farming in the Lowveld of Eswatini.

a. Given that the study focused on farmers who raise livestock on communal land, and did not consider ranchers on freehold land, a comparative study on the adaptation strategies employed by both types of farmers can be undertaken.

b. The study concluded that some of the perceptions about climate could be influenced by farmers' experiences of extreme climatic events; there is, therefore, a need for a refined study on farmers' perceptions of climate and empirical data to include extreme climatic events.

c. In light of the findings that no specific seasonal forecasts are available for livestock farming in Eswatini, there is need for a study on the development and use of climate forecasts for livestock farming.

d. A similar comparative study on perception, adaptations, and policy options can be done for the other physiographic regions of Eswatini. Such information will assist in developing a holistic study for the entire country.

7.7 Policy implications arising from the study.

The analysis of the results of this study revealed several potential policy implications or arrangements that ought to be addressed to promote climate change adaptation amongst farmers in the Lowveld of Eswatini. Out of these interventions mentioned to facilitate adaptation, the most important relates to training and capacity building. The proposed policy measures are discussed below.

The study suggests the implementation of policy to direct the capacity building on climate change and its impacts on livestock farming and other household operations. It has been proven in this study and other studies that the farmers' perception is linked to adaptation; therefore, a better education for farmers on the actual climate, the climate variations, climate extremes, and climate change impacts on the farmers activities would help promote the farmers' perception on climate change impacts or risks, and ultimately provide reason for them to adapt their farming activities.

There is need for policy to enable the provision and improvement of access to information, which includes all information needed to assist the farmers adapt to climate change. Such information can include: data, tools, and products such as weather and seasonal climate forecasts, farming inputs information (such as feeds, breeds, veterinary services, marketing products and market information). This information can be made available through various platforms used by the farmers such as the radio, television, and social media.

There is also a great need for policy to strengthen the provision of agricultural extension services. The study has shown that the farmers need timely, specific, and reliable information to make important adaptation decisions; however, the findings were similar to many sourced from Sub-Saharan countries, where traditional agricultural extension services, designed to address information needs, often fall short because of limited resources such as personnel and transport shortages, thus leading to information that only reach a few farmers (Enete & Amusa, 2010; Otene *et al.,* 2020). Therefore, there is need to strengthen extension services to ensure they provide information (including that on climate adaptation) to the farmers timely. There are several approaches that can be used for this; for example, integrating extension services with information communication technology, like sms or apps (such as WhatsApp), to ensure it reaches the farmers directly. Also creating a digital forum for farmers to discuss climate change, adaptation and extension services and also rate the extension service they receive from providers, is essential. This will increase the service and increase knowledge amongst the farmers. It must be noted that even without such specific digital integration of extension services, 51% of the farmers reported they use social media for climatic information.

The study revealed that policies that support and regulate climate change disaster relief are required. These regulations need to be more proactive in approach, and as such, the relief can be aligned to seasonal climate forecasts to ensure it is relevant to the forecasted climatic conditions. This will ensure that the relief is available in good time for the farmers to plan adaptation activities prior to the actual impact. For example, the government relief or assistance for provision or access to supplementary feed if provided on time will minimise livestock losses in times of extreme climatic events such as droughts.

There is need for a policy intervention for the provision of access to seasonal climate forecasts for livestock farming. The study revealed that there is a need for seasonal forecasts that are specific for livestock farming. Therefore, the meteorological and agro-meteorological agencies in Eswatini need to provide reliable, specific and timely seasonal forecasts that can be used for livestock farming. There also needs to be training and capacity building on how to interpret and use these forecasts, and also present the benefits of the use of these to the farmers. The training of the farmers needs to focus on using the forecasts for climate change risk management.

The study revealed that polices that improve access to markets for livestock are a key in ensuring adaptation. If access to markets is limited, adaptation approaches that include culling and selling of livestock are restricted; therefore, policies that facilitate access to markets are fundamental. Having better access to markets increases profitability of livestock farming and reduces the farmers' proneness to climate change impacts, and also increases their adaptive capacity. Linked to access markets, is a policy on access to inputs. Creating better access to inputs such as supplementary fodder to combat shortages during drought and access other livestock support services can assist in managing climate risk and adaptation.

Another policy implication linked to the results on the Lowveld of Eswatini is climate trend analysis which revealed that climate varied significantly within this region. Therefore, it is essential for the government to fund early warning infrastructure, such as meteorological monitoring stations, that would provide information which would assist in the production and establishment of more precise early warning mechanisms for the prediction of extreme climatic events, such as droughts.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

Request for permission to approach Tinkundla for data collection

c/o Ian B. van Zuydam
Private Bag 4
Kwaluseni, M201
Eswatini

06th June 2019

The Principal Secretary
Ministry of Tinkundla
P.O. Box
Mbabane

Dear Sir/Madam,

Re: Request for permission to approach Tinkundla centres in the Lowveld of Eswatini to interview livestock farmers at the Inkundla level

I am a PhD student at the University of South Africa conducting a study titled Assessing The Impacts of Climate Change on Livestock Farmers in the Lowveld of Eswatini Using A Modelling and Participatory Approach to Adaptation.

This study is expected to collect important information that will:

- Fill the information gap on climate change adaptation measures employed by livestock farmers in Eswatini
- provide information on how best of climate projections and forecasts can be used for climate change adaptation by the livestock industry in Eswatini.
- be used to develop a proposed strategy which can assist the farmers or policy makers in Eswatini to develop climate proofed livestock production systems.

I am requesting permission to approach the Tinkundla in the Lowveld of Eswatini and requesting their participation in the research because of the valuable contribution their participation can make in developing strategies to assist in the farmers and policy makers develop climate proofed livestock farming systems. If you grant permission, I would like to interview your staff between June to August July 2019.

I commit myself to keep the information provided confidentially. The participants in the study have the right to withdraw at any point of the study, for any reason, and without prejudice, and the information collected will be turned over to them. There are no known risks from being in this research. Participating in the study is absolutely voluntary.

I would greatly appreciate appreciation of your staff in this study. If you or your staff has any questions about the study itself, you are most welcome to contact me, my supervisor or if you have any ethical issues with the study Contact the research ethics chairperson as reflected below.

Thanking you in advance for your cooperation.

Yours sincerely,

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THE IMPACTS OF CLIMATE CHANGE ON LIVESTOCK FARMERS IN THE LOWVELD OF SWAZILAND USING A MODELING AND PARTICIPATORY APPROACH TO ADAPTATION

N.B. This information is confidential and is between the interviewer and the respondent. And for more detail on study see attached participant information sheet

Date:_____/_____/2020_				
Name of Chiefdom				
Name of Area:				
Name of Inkundla (Constituency):				
GPS:				
Land tenure (tick)	SNL		TDL	

SECTION 1: BIBLIOGRAPHIC INFORMATION

Name of respondent or code:			
1. Gender of respondent: Male		Female	

2. What is the age of the respondent:______years				(tick most suitable)	
18- 20 years		20-29 years		30-39 years	
40-49years		50-59 years		Above 60 years	

3. What is marital status of the respondent:				(tick most suitable)	
Single		Married		Widowed	
Divorced		Separated		Other specify_________	

4. What was the last class you attended at school:______ class				(tick most suitable)	
None		Primary education		Secondary school	
High school		Tertiary education			

5. Relation of the respondent to household head:				(tick most suitable)	
Self		Spouse		Parent	
Child		Grand child		Other specify_____________	

6. How many people live in this household? _________people				(tick most suitable)	
1-5 members		6-10 members		11-15 members	
Above 15 members					

5. Are you employed? (tick most suitable)				
	Yes		No	
	If yes, please state the type of your contract			
	Working full-time			
	Working part-time			
	If No, Are you self employed			
	Yes s	➤	Specify:__________________	
	No	➤		

6. What is your main occupation (tick most suitable)		
1.Employed		specify________________________
2.Farming		specify________________________
3.Business		specify________________________
4.No occupation		specify________________________

7. How long have you been keeping livestock:______years				(tick most suitable)	
0-5 years		6-10 years		11-15 years	
16- 20years		21- 25 years		>25years	

8. What are your major objectives of keeping these animals? (tick most suitable)						
	Cattle	Goats	Sheep	Pigs	Chicken	Donkeys
1. Major source of income						
2. Self-consumption						
3. Success as a farmer/wealth						
4. Customs (lobola, other)						
5. Other (specify)						

9. How many of each livestock do you own						
	Cattle	Goats	Sheep	Pigs	Chicken	Donkeys
1.Livestock Number Owned						
2.Highest Number Owned						
3.Period when had largest herd						
4.Highest number of livestock losses in drought year						

10. Livestock consumption per year						
	Cattle	Goats	Sheep	Pigs	Chicken	Donkeys
Number of livestock sold						
Number consumed at home						
Others (eg gifts)						

11. Livestock farming is _____ source of income? (tick most suitable)									
Not A		A Minor		A Moderate		A Major		The only	

12. What other farming activities is your household engaged in (tick most suitable)								
Grain farming (Maize/ sorghum)		Vegetable farming		Cotton		Sugar Cane		Other (specify)___________ _

13. Who manages the farm? (tick most suitable)					
Household head		Co- operative		Farmers' group	
Family members		Private company		Other (specify)_____________	

SECTION 2: CLIMATE CHANGE KNOWLEDGE FROM THE RESPONDENTS

14. Climate change and climate change information (tick most suitable)				
1.Do you know what climate change means?	Yes		No	
2.Are you aware of the problems associated with climate change?	Yes		No	
3.Do you receive information on climate change?	Yes		No	
4. Is this information on climate change related to livestock services	Yes		No	

15. Through what channel did you receive information on climate change related (tick most relevant)						
sources of information		Never	Rarely	Sometimes	Often	Always
1. Radio						
2. Television						

3. Newspapers						
4. Social media						
5. Family members or Neighbours						
6. Farmer-to-farmer extension						
7. Formal extension services						
9. Farmer cooperative						
10. Other specify):____________						

16. For what timeframe do you receive climate change information (tick all suitable)			
	Short-term (Day-week)	Medium term(Month-season)	Long-term (season to years)
Temperature			
Rainfall			
Weather forecasts			
Climate			

17. Does the climate change information you receive assist in decision making about livestock farming? (tick most suitable)						
Activities		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
1. Calving						
2. Supplementary feeding and water						
3. Dipping and pest management						
4. Culling or selling						
5. Restocking breed selection						
6. Other specify_____________________						

SECTION 3: CLIMATE CHANGE OBSERVATIONS AND EXPERIENCE

18. How has the climate been in the past 20-30 years? (tick most suitable box)						
Climate Indicators		Significantly increased	Increased	Not changed	Decreased	Significantly Decreased
1.Temperatures:						
2. Hot days						
3. Cold days						
4. Rainfall						
5. Rainy days						
6. Rainfall season						
7. Floods						
8. Winds						
9. Drought frequency						
10. Droughts Severity						

19. How has climate change affected the following household activities(tick most suitable box)						
Household Activities		Significantly Decreased	Decreased	No change	Increased	Significantly Increased
1.Crop yields						
2.Household income						
3.Domestic Water supply						
4.Family health						
5.Family diseases						

20. How has climate change affected the following livestock farming activities(tick most suitable box)

Farming Activities		Significantly Decreased	Decreased	No change	Increased	Significantly Increased
1.Grazing						
2.Livestock Water supply						
3.Livestock farming						
4.Livestock Disease and pests						
5.Milk Production						
6.Livestock Deaths						
7.Livestock birth rate						

SECTION 4: ADAPTATION MEASURES

21. Did you adapt to climate change?	
Yes	
No	

22. What adaptation measures or household coping strategies have you used to adapt to climate change at the household level? (tick most suitable box)						
Adaptation Measures		Never used	Rarely used	Sometimes used	Often used	Always used
1. Did nothing						
2. Changed crop variety						
3. Crop diversification						
4. Use extension services						
5. Planted late/ early						
6. Rely on remittances						
7. Seek employment						
8. Sold livestock						
9.Water harvesting and storage						
10. Adopted new technologies						

23. What measures (adaptation) have you used to deal with the changes in temperatures and rainfall in your livestock? (tick most suitable box)						
Adaptation Measures		Never used	Rarely used	Sometimes used	Often used	Always used
1.Provide supplementary feed, licks, salts						
2. Provide dip, medicines, deworming						
3. Sell livestock						
4. Provide water						
5.Changed animal breeds						
6. Diversified livestock (many types of livestock)						
7. Loaning of livestock (kusisa)						
8. Restocking						
9. Borrowed funds to look after livestock						
10.Used insurance						
11.Outside employment						
12.Use Early warning systems (forecasts)						
13.Engaged in mix crop and livestock						
14.Seek Education on livestock farming						
15Received food aid						
16.Nothing						

24. If you did not adapt what made you not to adopt adaptation measures? Tick most appropriate

Reasons		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
1. Lack of information						
2. Lack of money						
3. Not aware of climate change						
4. Do not know what to do						

25. What policy support would you like the government to implement to assist livestock farmers adapt to climate change						
Policy issue		Strongly Agree	Agree	Not sure	Disagree	Strongly Disagree
1. Provide markets for livestock						
2. Assist with breed diversification						
3. Training and capacity building						
4. Provision of relief						
5.Improved access to early warning systems						
6. Improved climate resilient breeds						
7. Improving grazing (fencing, rotation, etc.)						
8. Improve access to infrastructure						

SECTION 5. LIVESTOCK PRODUCTION

26. Please fill in the estimated amount spent on the following livestock activities in the previous year.	
Name of item	Amount (E)
1. Veterinary (inoculation, dosing, medicines)	
2. Supplementary feeds	
3. Purchase of breeding stock	
4. Purchase of commercial stock	
5. Transportation of animals	
6. Water	
7. Labour	
8. Infrastructure (housing, warehouse, etc)	
9. Services, advice and training	
10. Other (specify)	

27.How much average income do you generate from your livestock per annum				E______________
26. On average in different years how much do you sell your livestock for?		Wet year Amount (E)	Normal year Amount (E)	Dry year Amount (E)
	Cattle			
	Goats			
	Sheep			
	Pigs			
	Chicken			
	Donkey			
	Other___________			

Thank you for answering this questionnaire.

APPENDIX 2: INTERVIEW GUIDE QUESTIONS FOR THE KEY INFORMANTS

1. Consent process

Before the interview or discussion the researcher will seek consent. The researcher will follow the sequence below in seeking consent.

a. Thank you for agreeing to participate in the study. I am very interested to hear your valuable opinion on the impacts of climate change on livestock farming and how climate forecasts and projections have and can assist in adapting to climate change in livestock farming.

b. The purpose of this study is to determine:

- *The impacts of climate change*
- *The adaptation measures used in livestock production in the Lowveld of Swaziland focusing on both traditional and commercial farmers.*
- *How forecasts and climate projections assist or can assist farmers adapt to the impacts of climate change*

c. The information you give is completely confidential, and we will not associate your name with anything you say in the focus group.
d. We would like to tape the discussion so that we can make sure to capture the thoughts, opinions, and ideas we hear from the group. No names will be attached to the discussion and the tapes will be destroyed as soon as they are transcribed.
e. You may refuse to answer any question or withdraw from the study at any time.
f. If you have any questions now or after you have completed the discussion, you can always contact the researcher whose numbers are on the consent form.

2. Introduction:

a. Welcome

- Introduce yourself
- Who we are and what we're trying to do
- What will be done with this information
- Why we asked you to participate

b. Explanation of the process

- Explain the discusiion process.
- We learn from you (positive and negative)
- Not trying to achieve consensus, we're gathering information
- In this project, we are doing both questionnaires and key informant intervew discussions. The reason for using both of these tools is that we can get more in-depth information from a smaller group of people in focus groups. This allows us to understand the context behind the answers given in the written survey

c. Logistics

- The discussion will last about one hour

d. Turn on Tape Recorder

3. Discussion

a) Ask the Participant if there are any questions before we get started, and address those questions.

b) Introductions

c) Questions:

1. Let's start the discussion by talking about the impacts of climate change?
2. What adaptations have been used to adapt to climate change?
3. Have you heard about long term climate forecasts? And how have these assisted you to adapt to climate impacts?
4. Have you heard about long term projections? What do they indicate for you as a farmer?
5. Share with the farmers the latest long-term forecast and projections and ask how they will react to these.
6. Could you suggest ways and means in which climate forecast and projections could assist you better manage your livestock farming?

4. Thank you

That concludes our interview or discussion. Thank you so much for coming and sharing your thoughts and opinions.

APPENDIX 2: Ethical clearance and correspondence

UNISA university of south africa

CAES RESEARCH ETHICS REVIEW COMMITTEE

National Health Research Ethics Council Registration no: REC-170616-051

Date: 25/11/2016

Ref #: **2016/CAES/133**
Name of applicant: **Mr IB Van Zuydam**
Student #: **58548270**

Dear Mr Van Zuydam,

Decision: Ethics Approval

Proposal: The impacts of climate change on livestock farmers in the Lowveld of Swaziland using a modeling and participatory approach to adaptation

Supervisor: Prof WAJ Nel

Qualification: Postgraduate degree

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Approval is granted for the project, *subject to submission of the relevant permission letter.*

Please note that the approval is valid for a one year period only. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

Due date for progress report: 30 November 2017

Please note points 4 to 7 below for further action.

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 24 November 2016.

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and*

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principles expressed in the UNISA Policy on Research Ethics.

2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Research Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.*
4) *The research will be done at dip tanks. The owners/controllers of the dip tanks must give permission for the research to be conducted there.*
5) *Where will the questionnaires be stored after completion?*
6) *The use of photographs and recording devices must be stipulated in the consent form.*
7) *The consent form has been altered. The standard consent form must be used and may not be altered by taking out the headings.*

Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.

Kind regards,

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

NB: No's 4-7

Approval template 2014

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APPENDIX 4: ADAPTATION THEMES AND F ADAPTATION INTERVENTIONS

Theme	Policy Documents									Total
	Swaziland's Third National Communication to the UNFCCC.	National Climate Change Policy, 2016	The National Development Strategy (1997-2022)	Livestock Development policy 1995	National Food Security Policy for Swaziland 2005	Comprehensive Agriculture Sector Policy, 2005	National Drought Mitigation and Adaptation Plan (NERMAP) 2016 - 2022	National Development Plan 2019/20 – 2021/22	Swaziland Resilience Strategy and Action Plan (**SRSAP**) 2017	
Capacity building, extension, training, awareness and information sharing	2	4	3	9	2	12	5	3	6	**46**
Technology, innovation, research and development	5	3	3	11	4	12	1	1	0	**40**
Policies	3	3	7	4	2	14	2	1	0	**36**
Integrated rangeland or pasture management	4	0	5	4	2	*12*	0	2	1	**30**
Livestock breeding, diversification and intensification and marketing	1	0	4	9	3	*12*	0	0	0	**29**
Carrying capacity management and improvement	1	0	2	8	2	2	1	2	0	**18**
Disease, vectors and parasites management	0	1	0	3	2	9	0	0	0	**15**
Alternative livelihood and diversification	0	0	1	1	4	4	0	1	2	**13**
Institutional development and strengthening	0	1	0	8	0	0	0	0	3	**12**
Water supply	3	1	1	2	0	1	2	0	2	**12**
Total	**19**	**13**	**26**	**59**	**21**	**78**	**11**	**10**	**14**	**251**

APPENDIX 5: MULTICOLLINEARITY TESTS

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
	MNL_Age	.853	1.172
	MNL_Constituency	.814	1.229
	MNL_Employment_Status	.678	1.474
	MNL_Gender	.831	1.204
	MNL_Income_Livstck	.738	1.356
	MNL_Occupation	.684	1.463
	MNL_Marital_status	.832	1.202
	MNL_Size_Household	.872	1.147
	MNL_Crops_Farmed	.886	1.129
1	MNL_Own_Large_LU	.745	1.342
	MNL_Own_Small_LU	.848	1.180
	MNL_Education	.658	1.519
	MNL_Livestk_Keepin_Yrs	.675	1.482
	MNL_Livstck_Farming_Income	.725	1.379
	MNL_Livstck_Expenditure	.696	1.436
	MNL_Knowledge_CC	.751	1.331
	MNL_Access_2_CC_Info	.715	1.398
	MNL_Farm_manager_Is	.828	1.208
	MNL_Lost_To_Drought	.687	1.455

a. Dependent Variable: Temp_Perception

APPENDIX 6: SUMMARY OF KEY INTERVIEWS

TABLE A.6	Key Informant							
	1 Gilgal_Male	2. Sithobela Male	3 Lavumisa Male	4 Matsanjeni -F	5 Mpolonjeni -M	6 Mandlangemphisi_M	7 Mhlangatane_F	Summary
1. Let's start the discussion by talking about the impacts of climate change?	droughts frequency increased no longer grow maize input costs increased reduced water supply livestock deaths.	seen impacts on our livestock entire head of cattle wiped out and government food aid is limited to farmers with small herds no rainfall during growing season shift in rainy season from September to late November	severe impact. Farmers stopped cotton farming rains very erratic Crops only in irrigated areas el Niño serious deaths of livestock Some farmers lost over 40 cows	has had serious impacts on persons recently droughts (el-Niño) we were not to plant crops many farmers lost cattle. these impacts seem to be getting worse	impacts are severe but also have a challenge of bush encroachment and reduced grazing to settlements. This forced to also keep goats and cattle because goats can survive on the shrubs	impacts these are many affect our crops resulting in crop failure. some grow sugar can but have less impact. But regarding livestock it results in deaths costs to supplementary feed the livestock.	Climate change impacts are severe on both crops and livestock farming, in times of drought people lose their entire crops in winter and early spring they lose cattle due to lack of grazing	Severe impacts on both crops and livestock Dry land Crop failure during droughts Livestock deaths during droughts and El Niño Reduced grazing , and water availability Shifts in rain season Increased need for supplementary feeding
2. What adaptations have been used to adapt to climate change?	diversified my farming operations employed own business. reduced cattle or scaled back my cattle farming raising chickens -harvest rain water.	reserve funds over E40000 just to purchase supplementary feed reserve funds for winter watering for our cattle, work with other farmers to source and secure feed (hay) employed as community leader run businesses (shops)	have a tittle deed farm were we keep our cows have to provide water supplementary feeding as well as pesticides. sell cattle in autumn to minimise loses in winter. also purchase replenishment stock some focus on irrigated sugar cane farming.	adaptation requires money so it varies grow drought tolerant varieties, plant early stretch their growing season, livestock they cull their animals before the winter some farmers provide livestock watering.	We have to water our animals And provide supplementary feed I have diversified my livestock, cull the older cows during the year when food is abundant, migrate my cows in search for better pastures	I am now employed as a community leader. I diversified my farming activities keep every kind of livestock not only reliant on cattle but goats, chicken and pigs I also sell my livestock	diversified my farming operations, some farmers feedlot the cattle sending them to the market run my businesses I also provide supplementary feeding to my livestock cull those that need to be culled and put these trough the feedlot	Seek external income (Employed, businesses) provide water and supplementary feeding Diversified crops and livestock (Keep other livestock goats, chicken etc.) Use drought tolerant crop varieties Sell or cull livestock. Plant early

								Use input from extension services and climate forecasts
3. Have you heard about seasonal climate forecasts?	Yes on the radio	Yes we have mainly on the radio	Yes I have	Yes I have, they tell us about crop farming with associated advice	Yes but they focus mainly on planting dry land crops	Yes but they focus on mainly on crops farming	Yes	Yes – they more inclined to
4. How have seasonal climate forecasts assisted you to adapt to climate impacts?	About growing crops use them for growing grain They used for the choice of seed we choose. e.g. drought tolerant varieties based on this information.	Use them to determine if we have to sell our livestock To determine how much feed we might need Assist with decision making But they at times unreliable.	Use them for example for deciding if we must cull livestock because we fear for the worst. But not used for other activities	We use them to decide on seed varieties They not always reliable	used to decide what crops to grow and which varieties to use For cattle farming we use them to plan for the worst case scenario about culling livestock	On what to grow and when to plant We use them only to plan livestock activities such as supplementary and f if we must sell or not. But we need more assistance on how to use these	we use them for crop farming and I hardly use them for livestock farming, these are not always reliable	Mainly used for dry land crop farming, choosing the seed varieties and when to plant. Or what to plant They misleading or unreliable at times less used for livestock farming but are used to plan supplementary feeding with regard how much feed might be needed and when to culling
5. Have you heard about long term climate projections?	Yes but not in detail	Yes but not in detail, Climate impact will be worse	Yes, only more severe and extreme weather	Yes that temperatures will increase and we will have less rain	Yes increased temperature and less rain.	Just on the radio but nothing in detail,	Yes in general to Eswatini but not specific to my home area	Yes – but not in detail – mainly for Eswatini (increased temperature and reduced rainfall) – and they not specific to each area
6. What do long term climate projections indicate for you as a farmer?	heard rains might get less and temperatures rise the future does not look good	need to start planning for the long term e.g. fodder and cost might increase	Farming will be more challenging	it will be more difficult to farm in the future we will need to adjust the way we farm.	it indicate a more severe scenario than we currently know farming will be more challenging	It's difficult but there is a lot of uncertainty	I am not aware because they not specific to the home area	Lot of uncertainty Farming will be more challenging Might get costlier to farm Need to adjust or adapt the way we will farm
7. Share with the farmers the latest seasonal forecast ask how they will react to these.	Focus on farming farm goats raise chickens -invest in water harvesting.	Have to supplementary feed Might have to cull livestock Need to provide livestock watering)	have to provide water supplementary feeding sell cattle minimise loses in winter.	seasonal forecasts assist us to better plan what to grow and how to plan livestock farming and also which livestock to farm Need to provide supplementary feeding Medicines, water. Have to cull unproductive livestock	These forecasts are a benefit to the farmers they can assist in better planning farm activities from crops to animals. Provide info on what to plant, what to plant and when to cull animals Seems have to supplementary feed	Sometimes they unreliable I will maintain my livestock I could sell my unproductive livestock	They not very specific The forecast are for planning such as when I need to cull or feedlot my animals	Don't fully trust these Cull cattle Supplementary feed livestock Need to provide medicines Need to provide water for winter stock watering Plan adaptation or farm activities in line with this information Sell to minimise loses

8. Share with the farmers the latest climate projections ask how they will react to these.	Based on these projections say less grazing less grass so we will farm goats grow more sorghum and less maize grow is drought tolerant varieties	Based on this we might have to seek land to grow fodder Need to provide more supplementary feeding and watering. Have to diversify to small livestock mainly goats	The future looks uncertain we will not be able to grow crops livestock needs better management and diversification we will cull more to ensure we optimise grazing. keep goats because they more hardy to droughts livestock watering will be a big challenge Farming costs will increase (expensive) more supplementary feeding.	. The long term projections can be used for long term planning for e.g. use more climate resilient breeds of livestock and crops	The long term projections I am not sure of their use because this is way in the future	The projections indicate a wetter period maybe growing crops will be less risky More rain means more grass meaning less money spent on feeds this can change the way we farm	Well based on the projections this part might have slightly more rainfall and increased temperature Maybe it's not that bad as for other parts of the country. Based on these it means less costs for feedlotting because these will be more grass	Difficult to plan for its way in the future Central and southern region Plant drought tolerant grain There will be less grazing And water Need to invest in more resilient livestock e.g. goats Diversify livestock Need to invest in livestock watering Farming more expensive and risky Northern region Wetter might be better suited for current agriculture Will spend less on supplementary fodder Might be easier to farm
9. Suggest ways and means in which climate forecast and projections can assist you better manage your livestock farming?	-government must train farmers how to use forecasts -government also needs have policies to assist the farmers adapt more information sharing - projections must be reliable Now unreliable	need better understanding of such forecast training needs to be provided. forecast must be reliable information that can assist as to when to buy and sell livestock Government need to assist farmers with drought tolerant breeds	all forecast are good because they help with decision making. Forecast will assist us to plan our farming and also when we should sell our livestock to avoid losses. Such information help save money which can be lost due to livestock dying. these forecasts need to be more specific and informative to the farmers training on their use , current forecasts tend to focus maize and crop farming and less on livestock farmers. come to late or they are inaccurate.	-livestock farmers need to be trained how to interpret and use these They need to be specific for livestock farming . their timing needs to be correct and not only when the farmer is facing livestock deaths	For livestock the forecast can assist us plan supplementary feeding when is it optimal to sell or cull our livestock. .training and information of how to use these is required. The se need to be area specific	-climate forecast are sometimes not accurate They not reliable at times These forecasts are difficult to understand We should be taught on their use for agriculture besides crops. these must to be readily available to the farmers projections are difficult to use because they are for the distant future	-climate forecast need to be area specific, timely and easy to understand They currently difficult to understand more information on climate the better we can react our livestock. Projections maybe they better suited for government to plan and come up with initiatives to assist the farmers cope with long term climate impacts.	Forecast difficult to understand More training is required for them to understand them Forecasts not specific for livestock farming But more information is on dry land crop farming The forecast have reliability issues- (during last el Niño farmers were told it will be a normal year and they lost their crops) Forecasts need to be timely – shared early so the farmers can make informed decisions

								Forecast should also be area specific They can assist plan for the future activities on the farm such as when to sell livestock how much and for how long fodder is needed These should also be used by government to come with initiatives to assist the farmers. They can assist reduce expenditure which could be exerted by good planning