AN ANALYSIS OF CLIMATE CHANGE ADAPTATION STRATEGIES: A CASE STUDY OF SMALLHOLDER FARMERS IN LIMPOPO PROVINCE, SOUTH AFRICA

by

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I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

23/10/2023

SIGNATURE DATE

DEDICATION

The study is dedicated to my late husband Mr Onismus Musa Maringa and my late father Mr O.J. Mungedzi.

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ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
ADBI	Asian Development Bank Institute
AGRISA	Agriculture Sector South Africa
AFOLU	Agriculture Forestry and other Land Use
BASE	Bottom-up Climate Adaptation Strategies Towards a Sustainable Europe
BFAP	Bureau for Food and Agricultural Policy
CIGI	Centre of International Governance and Innovation
CDE	Centre for Development Enterprise
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DE	Department of Energy
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
DFID	Department of International Development
DNT	Department of National Treasury
DOA	Department of Agriculture
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EEA	European Environmental Agency
EPWP	Expanded Public Works Programme

FAO	Food Agriculture Organization of the United Nations
FG1P1	Focus Group 1 Participant 1
FG2P1	Focus Group 2 Participant 1
GCF	Green Climate Fund
GHG	Greenhouse gas
IDP	Integrated Development Plan
IIED	International Institute of Environment and Development
IIEP	Institute of International Economic Policy
ISRC	International Standard Recording Code
IPCC	Intergovernmental Panel on Climate Change
LDARD	Limpopo Department of Agriculture and Rural Development
LEDET	Limpopo Department of Economic Development, Environment and Tourism
MDG	Millennium Development Goal
NPC	National Planning Commission
NDP	National Development Plan
NGO	Non-Government Organisation
OECD	Organisation for Economic Co-operation and Development
PMT	Protection Motivation Theory
SA	South Africa
SANEDI	South African National Energy Development Institute

SANWPWP	South African National Water Policy on White Paper Policy
SAWS	South African Weather Services
SDG	Sustainable Development Goal
SLF	Sustainable Livelihood Framework
Stats SA	Statistics South Africa
TIPS	Trade and Industrial Policy Secretariat
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNISA	University of South Africa

ABSTRACT

Climate change is a worldwide problem as it affects agriculture which is the livelihood of the poor. The study used the Protection Motivation Theory to understand how smallholder farmers protect themselves from climate change impacts and what motivates them to do so. The purpose of this exploratory sequential mixed method design was, firstly, to explore and understand climate change through the insights and experiences of smallholder farmers and government officials in Limpopo Province. Secondly, to uncover and assess smallholder farmers' adaptation techniques to varied climatic circumstances.

This was a case study that used a mixed approach following two phases. To collect data, 62 smallholder farmers under Ba-Phalaborwa Local Municipality and 12 key informants from Limpopo Department of Agriculture and Rural Development were chosen using purposive and random selection. Questionnaires, a focus group guide, key informant interviews, and field observations were used to collect data from both qualitative and quantitative phases. The mixed data analysis used joint data displays, which exhibited findings from qualitative and quantitative data together for an overall research interpretation. Extreme climatic events; high socioeconomic losses; a lack of resources; limited adaptation techniques; and agricultural investment were the themes found in this study. These themes developed the questionnaires to collect quantitative data.

Climate change has a detrimental impact on smallholder farmers owing to a lack of physical, human, institutional and financial resources. Smallholder farmers hardly survived climate shocks due to inadequate institutional support. These impediments limited smallholder farmers' capacity to adopt and apply several adaptation strategies. Despite that smallholder farmers adopted cost free strategies, such as manure, mulching, crop rotation and planting indigenous crops, to survive harsh climate impacts, strategy such as drilling borehole has been found to be maladaptive, possibly to cost government lots of money in the future due to a reduced groundwater level. Hence, there is need for decision makers to improve and strengthen climate adaptation policies.

Moreover, the findings revealed that Limpopo Province experiences climatic events such as heavy rainfall, droughts, thunderstorms, floods and veld fires. Hence, educating farmers about climate change has been found to be a pre-requisite. Limited collaboration between government departments was found to be the reason for the lack of availability and accessibility to resources to farmers. Harsh climate conditions can be managed if stakeholders pool their resources for the benefit of farmers and to boost the economic growth of the country.

Key terms: Climate; Climate change; Climate change adaptation; Adaptation strategies; Vulnerability; Adaptive capacity; Autonomous adaptation; Planned adaptation; Livelihood; Smallholder farmers

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

> *"Together with all the nations of the world, we are confronted by the most devastating changes in global climate in human history. The extreme weather conditions associated with the warming of the atmosphere threaten our economy, they threaten the lives and the livelihoods of our people, and – unless we act now – will threaten our very existence" (Ramaphosa 2019).*

Traumatic climate change results are rapidly being felt around the world, changing our living surroundings and jeopardising people's livelihoods (Ng, Lwin & Pang 2017). Climate change is a major global concern since it is related to a range of issues such as economic development and poverty reduction (United Nations Educational, Scientific and Cultural Organization [UNESCO] 2010:2). Climate change poses a major threat to the economic growth of developing countries and the livelihoods of individuals (Chambwera & Sage 2010:7). Even though poorer countries contribute less to climate change, they bear the brunt of its consequences (UNESCO 2010:2). Climate change has a detrimental impact on important sectors of the economy, including agricultural, social, and economic growth. According to Kissinger et al (2014:2), agriculture is the most impacted industry in many poor countries. Climate change, as noted by Raghuvanshi, Ansari and Amardeep (2017:154), has a negative impact on crop yields, farming practices, and the economy.

In South Africa, the Western and Northern Cape, Gauteng, Limpopo, and eastern KwaZulu-Natal, in particular, have observed warming that is over two-fold the rate of global warming (SA Department of Environmental Affairs [SA DEA] 2017b). It is well documented that there is an increase in the magnitude and frequency of extreme climatic events, such as floods and droughts, due to changes in climatic conditions in South Africa (Musvoto, Nortje, De Wet, Mahumani & Nahman 2015:15). Schulze (2016:57) states that extreme climatic events, such as droughts and floods, have impacted many people in South Africa. These climate-related hazards have destroyed livestock, crops, land and other assets which are the main sources of livelihood of many smallholder farmers. For example, in South Africa, severe drought during 2016 accelerated the depletion of natural grazing resulting in livestock death (Zwane & Montmasson-Clair 2016). This forced the slaughtering of livestock due to fodder unavailability (Agri South Africa 2016:5). Some livestock farmers were forced to move their livestock to other favourable grazing camps (Agri South Africa 2016:8).

Zwane and Montmasson-Clair (2016:2) further perceive that agriculture in South Africa is facing different risks which are associated with climate change such as changes in rain patterns, an increase in evaporation rates, higher temperatures, an increase pests and diseases, and changes in diseases and pest distribution ranges, reduced yields and a spatial shift in optimum growing regions. These numerous threats are interconnected with climate change, and they make South African agriculture vulnerable to climate change (SA Department of Agriculture, Forestry and Fisheries [DAFF] 2013:7). Food and Agriculture Organization [FAO] (2010) is of the view that the threats exacerbate farmers' challenges. Smallholder farmers are hardest hit by climate change (Harvey, Rakotobe, Rao, Dave, Razafimahatratra, Rabarijohn, Rajaofara & MacKinnon 2014:14). They experience many difficulties when coping with various climatic disasters (DAFF 2015:15).

Individual adaptive measures at the farm level have been discussed in previous studies (Chinwe 2010:17; Dang, Li & Bruwer 2012:256). However, Lobell and Burke (2010) are concerned that not all strategies are available to all farmers because these strategies may not be well documented (Shrestha, Raut, Swe & Tieng 2018:40).) For this reason, research about adaptation strategies is imperative due to natural disasters, such as floods and drought, amongst others, that are a serious threat to food security (Elum, Modise & Marr 2016:3).

Adaptation refers to a process, action or outcome in a system (household, community, group, sector, region, country) for the system to cope better with, survive or adjust to changing conditions, stress, hazards, risks or opportunities (Smit & Wandel 2006:282). In the context of climate change, adaptation strategies include all practices used by smallholder farmers to either adapt to or mitigate the effects of climate change and variability (Kuwornu, Al-Hassan, Etwire & Osei-Owusu 2013:233). Environmental conditions are just one of the numerous elements that a farmer will consider when deciding the crops to produce and the livestock to raise (Maddison 2007).

Hassan and Nhemachena (2008) posit that the damage caused by climate change can be reduced when farmers plan and respond to the changes. Hence, analysing climate change adaptation strategies will assist farmers to discover ways to adapt to various negative climatic events (Hassan & Nhemachena 2008). These strategies are vital for the protection of livelihoods and to safeguard food security (Bryan, Deressa, Gbetibouo & Ringler 2009:414).

The study conducted by Uddin, Bokelmann and Entsminger (2014:225) found that changing the timing of planting, using heat and drought resistant varieties with new cultivars, practicing soil and water conservation techniques, using fertilisers, irrigation and diversification to non-farm activities were some of the adaptation strategies that are practiced at farm level in response to climate change. According to Ncube, Madubula, Ngwenya, Zinyengere, Zhou, Francis, Mthunzi, Olivier and Madzivhandila (2016:11), adaptation strategies conducted in Lambani village, Limpopo Province, are: planting drought resistant crops, using high yield varieties, irrigation systems, using organic fertilisers, conventional farming systems and a zero/minimal tillage farming system. Another study conducted in Limpopo found that strategies used were: soil management, water management and subsidies and insurance (Maponya & Mpandeli 2013).

Adaptation is understood and ratified by many countries as a suitable and necessary strategy to address climate change by establishing and applying existing and new adaptation strategies while reducing the impacts of climate change (Below, Artner, Siebert & Sieber 2010; DAFF 2015:13; Gebrehiwot & Van Der Veen 2013:31). The focus of this study was therefore to discover and analyse climate change adaptation strategies practiced by smallholder farmers in Limpopo Province. The question used to assist in achieving this objective was: “What strategies do smallholder farmers in the area of the study practice in order adapt to the extreme weather events?”

1.2 Problem statement

Human activities are the main drivers of climate change leading farmers to be exposed to various climatic risks. Climate change poses various risks to South African agriculture, including changes in rain patterns, evaporation rates, temperatures, pest and disease distribution, reduced yields, and changing optimum growing areas (Zwane 2016). Moreover, climate change may deplete water sources, resulting in shortages of water, which has serious effects for human health, agriculture, and the ecosystem. For example, in water-scarce areas, people may lack access to clean drinking water, which can lead to a variety of health issues, including waterborne infections (StatsSA 2023). Furthermore, water scarcity can have an impact on agricultural production, potentially leading to food shortages and increased food costs.

In South Africa, smallholder and communal farmers have been shown to be more vulnerable to drought due to their geographic concentration in less favourable climatic places, lack of resources, and reliance on their own production for household food security (AGRI SA 2016:17). In Limpopo Province, Maponya and Mpandeli (2013) and Ncube et al (2016) conducted studies in various communities in Vhembe district on the effects of climate change on agriculture. Their findings discovered that, even though smallholder farmers used different methods to adapt to climate change, they have been experiencing challenges.

Despite extensive research on adaptive measures at farm level (Dang, Li & Bruwer 2014), there is a research gap on how smallholder farmers in Ba-Phalaborwa local municipality cope and adapt to different climate shocks. Chinwe (2010) and Lobell and Burke (2010) are concerned that there is little research on smallholder farmers' responses to climate change. Furthermore, according to FAO (2024), rural populations and their climate vulnerability receive less attention in national adaptation policies. For example, just 6% of 4164 climate actions in Nationally Determined Contributions (NDC) and National Adaptation Plans (NAPs) from 24 countries refer to farmers in rural communities (FAO 2024).

According to the researcher’s knowledge, no study in the area has used a sequential mixed method design. In addition, limited studies have revealed non-verbal findings.

This study will improve policies and programmes aiming at reducing farmers' vulnerability to climate change in rural areas as it presents the views of farmers. To protect farmers' livelihoods and prevent low agricultural output, decision makers need to develop appropriate adaptation strategies that consider farmers’ perspectives on climate change, its impact, barriers to adaptation, and the way they protect themselves from the adverse effects of climate change.

1.3 The purpose of the study

This study explored climate change which is defined as the extreme weather events, such as droughts, triggered by increased GHG emissions from agriculture that lead to flooding and the loss of arable land due to desertification and soil erosion, reduced agricultural yields and crop failure, and loss of livestock (Besada & Sewankambo 2009:9). The purpose of this exploratory sequential mixed method design was, firstly, to explore and understand climate change from the views and experiences of small focus group discussions of smallholder farmers and key informants in Limpopo Province and, secondly, to discover and analyse the strategies which these smallholder farmers used to adapt to the various climatic conditions.

1.4 Research aim, questions and objectives

The purpose of an adaptation strategy is to increase the capacity of the system to cope with the severe harm caused by climate change events (Nhemachena 2007:3). The general question for this study was:

> *What adaptation strategies are adopted by Gravelotte, Priska and Selwana Secondary Cooperative in Limpopo Province to improve their agricultural productivity and to minimise the extreme weather events caused by climate change?*

Based on the above question, this study addressed the following sub-questions:

- What is the understanding of smallholder farmers on climate change and its causes?

- To what extent does climate change affect agriculture in the area of the study?
- What appropriate strategies do smallholder farmers in the area of the study practice in order to adapt to the extreme weather events?
- What are the challenges smallholder farmers are facing when adapting to climate effects?
- What motivates smallholder farmers in Limpopo Province to adapt to climate change and how can farm level adaptation be improved?

The objectives of the research were as follows:

1. To explore the smallholder farmers' understanding of the concept of climate change.
2. To determine the extent of the effects of climate change on agriculture.
3. To analyse the appropriate strategies practiced by smallholder farmers when adapting to climate change.
4. To assess the challenges encountered by smallholder farmers when adapting to climate change.
5. To analyse factors motivating smallholder farmers in Limpopo to adapt to climate change and to provide solutions on how to improve adaptation at farm level.

1.5 Scope of the study

The geographical area of the research and data gathering place is GRASP Secondary Cooperative in Ba-Phalaborwa Local Municipality in Mopani District of Limpopo Province in South Africa. The study's focus was on smallholder farmers who have suffered from the effects of climate change. The study focused on techniques chosen and implemented by smallholder farmers to protect themselves from various climate change events; hence the scope focused on adaptation solutions, based on their experiences of preserving their livelihoods.

The study investigated the direct and indirect effects of climate change on agriculture and how climate change impacts the livelihoods of smallholder farmers. The barriers that prevent smallholder farmers from adopting and applying adaptation strategies were covered. For adaptation to be successful, stakeholders need to collaborate; hence the scope also describes how the engagement of stakeholders may overcome these barriers.

Mopani District Municipality has the conditions to produce fruits and vegetables. Although the characteristics of the smallholders fitted the criteria that were used, they differed in terms of resources such as land ownership. The literature review assisted the researcher to gain an in-depth understanding of the concept of climate change (Randolph 2009). The review covered topics such as international policies, critical climate change stakeholders, climate change observations and projections, impacts and strategies from other countries. The literature review helped the researcher to identify the theoretical framework that served as a guide to this research (Randolph 2009). The qualitative findings allowed the researcher to develop an instrument to collect quantitative data. The qualitative and quantitative data were analysed separately and later they were combined using joint display analysis. The sequences of these two instruments are discussed in Chapter 3.

1.6 Limitations of the study

Limitations are events and circumstances that emerge in a study and cannot be controlled by a researcher (Simon & Goes 2013). According to Ioannidis (2007:324), limitations in research cannot be avoided. Researchers use limitations to uncover, investigate and improve on recent research conducted (Ioannidis 2007:324). Due to limited resources, this study did not use content analysis to hypothesise the relationship between concepts.

The study focused on analysing the strategies for climate change adaptation practiced by smallholder farmers who are fruit and vegetable producers in Ba-Phalaborwa Local Municipality. This is a limitation as farmers in other areas outside the study and those who were not fruit and vegetable smallholder farmers were excluded.

The researcher was unable to reach all participants due to the COVID pandemic. During participant selection, some prospective participants were found to be deceased, while some participants did not want to participate because they were afraid and others withdrew during the data collection. These participants were replaced. The Department of Agriculture and Rural Development in Limpopo participated in this study to improve the findings. Due to resource constraints, the study also encountered methodological challenge of not testing relationship between variables. Other researchers may further explore in this area using content analysis. Although the study's limitation is that it cannot be generalised to other parts of the country, it is hoped that the recommendations that have been made will encourage and motivate farmers in the study area and elsewhere to start practicing farm level adaptation methods that will improve their agricultural production and contribute positively to their livelihoods.

1.7 Rationale of the study

In South Africa, agriculture is the source of livelihood of the people living in rural areas. For example, Ncube et al (2016) highlight that 80% of farmers in Limpopo practice agriculture for living. Climatic indicators such as rising temperatures, shifting rainfall patterns, and an increase in the frequency of extreme weather events and threats on food security (Intergovernmental Panel on Climate Change [IPCC] 2019) are amongst the reasons for conducting this study. Without effective mitigation and adaptation, losses and damages will continue to disproportionately affect the poorest and most vulnerable populations. Literature gap, as described in the problem statement, that limit climate change adaptation of smallholder farmers, along with problem of lack of documentation leading to few strategies available to farmers is an additional motivation to carry out this study. The other reason for undertaking this research is to contribute to the body of scientific information on this topic. This will help to add to the work of other researchers who have published on the topic under inquiry.

Emissions are expected to increase, resulting in a median global warming of 2.2°C to

3.5°C due to weaker rules and regulations (Intergovernmental Panel on Climate Change 2023). In South Africa, there is a growing concern on access to accurate information and forecasts which is required in order to prepare for the harmful effects of climate change and make informed decisions (Department of Environment, Forestry and Fisheries 2020). This demonstrates the policy gap issue that requires urgent attention to the implications of climate change. This brings us to the other reason for conducting this study which is to fill a policy gap by providing relevant information that will help policymakers understand the current state of climate change in preparation for addressing its adverse effects.

The reason that agriculture is the source of livelihood for smallholder farmers and many other people, particularly in rural areas, may motivate climate change stakeholders to understand climate change from the experiences of smallholder farmers, its impact on agriculture, challenges smallholder farmers face when adapting to climate change and their adaptation strategies. With South Africa's recurrent droughts and floods (Johnston et al 2024), this study will help smallholder farmers to reduce the effects of climate change through adapting to the strategies recommended by this study. Smallholder farmers are vulnerable to climate change due to their lack of adaptive capacity, hence, the NCCAS aims to empower vulnerable communities by increasing their resilience and adaptive capacity (Department of Forestry, Fisheries and the Environment [DFFE] 2020). The researcher believes that vulnerable groups, such as smallholder farmers, can provide valuable insights and contribute to good decision-making.

1.8 Significance of the study

The study is significant since it investigated climate change from the perspectives of farmers. The study also examined the effects of climate change and the challenges that farmers face while adapting to its negative consequences. The study provides a better understanding of farmers' and governments' responses to climate change, with the goal of enhancing farmers' livelihoods and improving economic growth. As a result, this study will help in the integration of current climate information into decision-making and the promotion of effective climate risk management strategies.

It is envisaged that this study will enable smallholder farmers in the Ba-Phalaborwa Local Municipality to protect themselves from extreme climatic events by using adaptation methods. The study adds to the limited body of literature on climate change and adaptation in South Africa. Furthermore, it will improve agricultural practices and management systems to avoid food security challenges as climate change unfolds (Fan, Fei & McCarl 2017:1). The study supports smallholder farmers to improve agricultural output by suggesting effective adaptation strategies (Fosu-Mensah, Vlek & MacCarthy 2012). Finally, the study fills the practical gap through providing practical solutions to the problem in Chapter 5.

The study will create an enabling environment for smallholder farmers by pooling resources from multiple stakeholders to solve the issue of climate change climate. This will make resources to be easily available and accessible to smallholder farmers leading to improved adoption of strategies and improved livelihoods by smallholder farmers.

1.9 Definition of key concepts used in the study

In this section, concepts that were used in this study are described briefly.

The term "**climate**" is used to describe both the average weather and the state of the climate system, which includes statistics in the form of the mean and variability of relevant quantities over time scales ranging from months to years to decades to centuries (FAO 2015:29; Nwankwoala 2015:225; Schulze 2016:62). In this study, temperature, precipitation, relative humidity, and wind are examples of climate variables.

Climate change is defined in this study as extreme weather events, such as droughts, caused by increased GHG emissions from agriculture, floods, droughts and the loss of arable land due to desertification, the removal of topsoil, and low agricultural yields resulting in crop failure and livestock loss (Besada & Sewankambo 2009:9). The study further includes climate risks, climatic hazards, disasters, or natural disasters, extreme climate events, and anthropogenic climate changes.

A **livelihood** is defined in this study as a method of earning a living (Chambers and Conway (1991). Herding, hunting, fishing, agriculture, collecting, paid work, trade and hawking, artisanal activities, such as weaving and carving, begging, theft, and other activities are examples of rural livelihoods (Chambers & Conway 1991). The study includes farming and non-farming activities as part of farmers' livelihoods.

In this study, **adaptation** is the process through which people, communities, and governments respond to climate change or other stimuli to reduce their sensitivity or vulnerability to negative consequences or harm potential (Bradshaw, Dolan & Smit 2004:199). The study includes efforts by government, the private sector, farmers, individuals and others.

Moser and Ekstrom (2010:22-26) explain that reacting to present and future climate changes necessitates the engagement of social-ecological systems. Adaptation, as explained by Moser and Ekstrom (2010:2), helps the process of identifying and discovering obstacles. The rate of climatic change, rates of economic development, population change, ecosystem rearrangement, and technological innovation all influence the adaptability of human and natural systems (Klein et al 2014:902).

Autonomous adaptation, in this study, is defined as farmers' responses to changing precipitation patterns, such as adjusting planting, sowing, and harvesting dates, among other things (FAO 2007). It includes techniques employed by smallholder farmers to adapt to the impacts of climate change.

Planned adaptations are defined as public (government, non-governmental organisations [NGOs], and other groups) efforts to provide solutions to problems that autonomous actions cannot fully address (Fan et al 2017:5). The efforts include policies, programmes, projects, and any intervention by government and private sectors to address climate change.

Climate vulnerability is defined as inability to deal with various climatic shocks due to limited socio, economic, environmental and institutional factors. For example, limited education, lack of income, water scarcity and lack of climate information are examples of climate vulnerability.

The concept of **natural disasters** in the literature emphasises several elements such as assets, means of livelihood, group, ethnicity, gender background, and poverty, which are likely to demarcate populations that are vulnerable (Paavola 2004).

Adaptive capacity is the ability of a system to change its traits or behaviour to increase its coping range under current or future climatic variability (United Nations Development Programme 2004). Adaptive capacity can be general (a population's ability to cope with a wide variety of climatic, socioeconomic, environmental, or other pressures) or particular (a population's ability to cope with a specific present climate). In this study, adaptive capacity means availability and accessibility of resources at national and farm levels to address climate change effects.

Climate variability (CV) is defined by Schulze (2016:63) as any divergence from the long-term predicted value (the mean) and other statistics (such as the incidence of extremes) of the climate over all time and spatial scales beyond that of individual weather occurrences. Drought caused by El Nino in southern Africa is one example. Farmers must develop suitable coping mechanisms in response to such variabilities (Mugambi 2017:115). Climate variability is defined as changes in rainfall and temperature patterns causing hazards, such as floods, veld fires, heat waves, droughts, and other disasters, that destroy farmers’ livelihoods.

A **strategy** is a long-term plan meant to address the aims and objectives that an organisation wants to attain (Nickols 2008:8). Strategies can be implemented by policies and initiatives that are part of broader strategies (OECD 2006:21). A country's climate change adaptation strategy is a broad plan of action for dealing with the effects of climate change such as climatic variability and extremes. A climate change adaptation strategy is a collection of policies and initiatives that may be utilised to reduce vulnerability in a given nation (OECD 2006:21).

Adaptation techniques and behaviours can range from short-term coping to longer-term plans (Moser & Ekstrom 2010). Examples in this study included government legislations, programmes and projects that are implemented to help farmers to adapt to climate change.

Smallholder farmers refers to rural farmers, particularly in developing countries, who rely on family labour and farming being their primary source of income (Morton 2007). When compared to other farmers in the industry, these farmers have fewer resources (DAFF 2012:1). Smallholder farmers inhabit small plots of land and farm a limited number of cash and subsistence crops (DAFF 2012:1). Smallholder farmers are classified in this study based on their individual characteristics, farm size, resource distribution between food and cash crops, livestock, off-farm activities, use of external inputs and hired labour, income and expenses (Alliance for Green Revolution in Africa 2014:20). In addition, this study defines smallholder farmers as farmers who are farming with crops and livestock. Participants, respondents, farmers are used to define smallholder farmers in this study.

1.10 Chapter layout

The study is organised in five chapters. The first chapter introduces the study and covers the problem statement, study purpose, objectives, and questions. This is followed by the scope of the study, limitations, rationale, significance and definition of concepts. Chapter two discusses PMT as the theoretical framework on which the chapters in this study were built. In addition, the chapter discusses the literature review covering global and South African climate change context. Chapter three is the methodology chapter covering the description of study area, the research philosophy, approach and design. Population of the study and sampling, data collection methods, and data analysis methods and processes are also discussed in this chapter.

Chapter four discusses secondary and primary findings from this study. The chapter covers farmers' socioeconomic profile, farmers' understanding of climate change, the extent of impacts of climate change, the challenges they face when adapting to climate change, the strategies they use to adapt to the effects and government intervention to these impacts. Chapter five discusses the summary of findings, how the study purpose and objectives are achieved, study contributions, conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter introduces Protection Motivation Theory (PMT), the theoretical foundation that underpinned this research. This is followed by an exploration of climate change experiences around the globe and the drivers of anthropogenic climate change. The chapter reviews South Africa's climate change projections to better understand the rate at which climate change hazards occur. Climate change adaptation strategies, potential risks and impacts, climate change adaptation measures, as well as the challenges that smallholder farmers encounter when adapting to the effects of climate change are discussed in the literature review.

2.2 Protection Motivation Theory as a theoretical framework of this study

The theoretical framework adopted for the study was Protection Motivation Theory (PMT). The justification for using the PMT model was that it was developed by Rogers (1975) to gain a greater understanding of how and why people respond to possible threats to their safety and health (Clubb, Joshua & Hinkle 2015:2). This study used PMT to formulate research questions and objectives that are described in Chapter 1. This explained the climatic threats and their impacts from the experience of smallholder farmers and key informants. Moreover, the framework has helped the researcher to provide recommendations on how climate change stakeholders can improve smallholders' adoption of adaptation strategies.

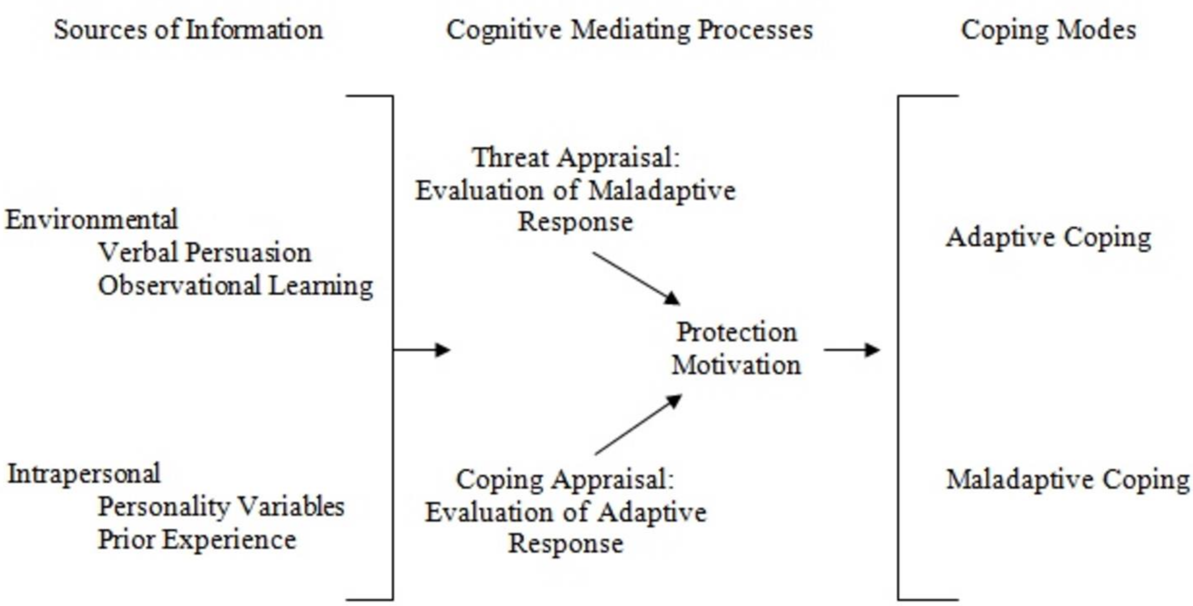


Figure 2.1: Protection Motivation Theory

(Source: Floyd, Prentice-Dunn & Rogers 2000)

2.2.1 Applicability of PMT Theory in this study

PMT has been used in this study to explore smallholder farmers' experiences with climate change and how they cope with these experiences. The framework identified the strategies for dealing with the dangers posed by climate change. The term “danger” is frequently used in climate change communication to create anxiety to encourage proposed actions (Howell 2014). The terms “danger” or “threat” addressed questions such as: “In what ways is climate change threatening farmers?”, “How have farmers observed the impacts of climate change and its implications in the study area?” and “What motivates smallholder farmers to adapt to the consequences of climate change?”

According to PMT theory, these questions are answered if farmers have concerns and feel that climate change is a threat (Gbetibouo 2009). The assumption is that, through PMT, farmers provide responses on how they protect themselves from climate change challenges and which measures they intend to employ to mitigate and/or adapt to the effects of climate change. Based on PMT, people are motivated to prevent a threat if the threat is perceived as frightening to them (Janmaimmol 2017:4) and they believe that the proposed measures will protect them (Tannenbaum et al 2015). The framework also fosters the adoption of adaptation techniques that are appropriate and realistic.

Ghazali, Azadi, Kurban, Ajtai, Pietrzykowski and Witlox (2021) summarise PMT into five factors under the headings of “risk evaluation process” and “adaptation evaluation process” that must be considered. Risk evaluation is divided into two parts. The first part is the *perceived probability* which describes how farmers understand their exposure to climate events. The second part is *perceived intensity* which indicates how farmers assess the danger of the consequences of climate change (Ghazali et al 2021).

The adaptation evaluation process comprises three parts. The first part is the farmers’ capability to perform the coping strategies; the second part is whether the coping strategies for protecting farmers under climate change are essential and appropriate; and the third part is the perceived adaptation costs of adopting the coping strategies (Ghazali et al 2021). The PMT model determines the change of attitude and decision making with reference to adaptive strategies (Ghanian, Ghoochani, Dehghanpour, Taqipour, Taher & Cotton 2020). Tazeze, Haji, and Ketema (2012) argue that farmers with education and experience are assumed to have knowledge and information about climate changes and are therefore expected to utilise these skills to respond to threats caused by climate change.

According to Imenda (2014) and Adom and Hussein (2018), PMT theory assists researchers in mapping out the research topic, investigating the problem, and determining the meanings from the data studied. This theory underpinned the research strategy, methodology, and strategies employed in this study (Rocco & Plakhotnik 2009:123). According to Imenda (2014), the framework assesses whether the study findings agree with the framework that has been employed to analyse and evaluate data to provide rigour.

2.2.2 Threat appraisal as an element of PMT

In this study, threat assessment was used to identify, describe, analyse and discuss the most prevalent extreme climatic threats noticed by key informants and smallholder farmers, the effects of such threats on farmers, as well as the repercussions. A threat is a warning to recognise danger and follow advice to avoid negative consequences. “Threat appeals” and “fear appeals” are terms that are used interchangeably (Pang, Yan & Cameron 2006). A threat is an external stimulus variable that exists whether a person knows it or not. A person who perceives a threat believes the existence of that threat (Witte 1992:332). The most common message postulated by a threat is the severity of the threat (Witte 1992). Fear, on the other hand, is only an outcome of a perceived threat, based on the distinction between the threat as a stimulus and the threat as an outcome (Pang et al 2006).

A threat appraisal process (Gebrehiwot & Van Der Veen 2015:590) comes before a coping appraisal. This is the primary process (Sun, Wang & Shen 2020) which is addressed by coping strategies (Janmaimmol 2017:4) which is the secondary process (Sun et al 2020). Sun et al (2020) advise that there should be a sequence when making decisions for both threat and coping appraisals and that the appraisals should be interdependent. In the threat appraisal process, an individual evaluates situations that are threatening (perceived probability) and the likelihood of the occurrence of the threatening situation (Sun et al 2020). These two appraisals work together to produce a decision based on protection motivation which may be affected by obstacles (i.e., beliefs and opinions about the viability and consequences of a behavioural option) that prevent the specific course of action (Bagagnan, Ouedraogo, Fonta, Sowe & Wallis 2019).

2.2.3 Adaptation appraisal

In this study, adaptation evaluation was used to determine availability and accessibility to farmers of resources such as human resources, extension services, banks, access to land, water, and agricultural inputs, climate information, and others to deal with climate change as a threat. To determine the level of adaptive capacity, the socioeconomic indicators were identified, analysed, and discussed. Some of these socioeconomic factors included farmer education, income, farm size, gender, age, among others. Coping and adaptation strategies applicable to farmers in the area of the study were discovered and discussed during the data collection procedure.

One of the most important aspects of adaptation is addressing the vulnerabilities to climate change that constrict farmers' adaptive capabilities (Bagagnan et al 2019). According to the coping appraisal, if farmers believe they can tackle climate dangers, they are motivated to protect their farms and are more likely to execute an adaptation measure (Bagagnan et al 2019).

People's adaptive responses are guided by their knowledge of severity, vulnerability, and reward (Ghanian et al 2020). Adaptation is a measure taken to lessen a system's susceptibility to a known climate risk. In the context of agriculture, all adaptation measures fall into two categories that either lessen the sensitivity of a system or raise its capacity for adaptation (Hunter & Cronin 2020). To cope with the threat, people have to believe that there are adaptation actions to eliminate the threat, that they are able to carry out the task and that the cost of carrying out the adaptive response is reasonable (Van Duinen, Filatova, Geurts & Van der Veen 2015).

2.2.4 Maladaptation

The concept of maladaptation is used to determine whether the adaptation options chosen and implemented exacerbate the effects of climate change. Maladaptation is used to study adaptation outcomes that fail to reduce climate-related risk or result in excessive costs (Juhola, Glaas, Linnér & Neset 2016). Maladaptive responses (threat appraisal) include avoidant reactions (e.g., denial of the threat, wishful thinking, fatalism) and "wrong" adaptations that cause climate change damage although they are not intended to do so (Grothman & Path 2005). The concept of maladaptation has evolved from unsuccessful adaptation to adaptive behaviours that deplete resources, limit future alternatives, exacerbate the issue for vulnerable populations, or shift the burden of finding solutions to subsequent generations (United Nations Environment Programme 2019).

An adaptation strategy that exacerbates environmental circumstances, reduces social and economic values, and/or increases GHG emissions resulting in eroding sustainable development is depicted as negative (Juhola et al 2016). The result of a climate change adaptation activity need not be unfavourable; it could simply be a failing strategy that increases vulnerability. However, if the action increases vulnerability, adversely effects actors' or organisations' capacity to respond to climate impacts or hinders their efforts to realise sustainable development goals (economic, environmental, or social), it might be deemed maladaptive.

2.3 Global climate change experiences

Never in modern history has humanity encountered such a wide range of risks and dangers, both known and unknown, while interacting in a world that is highly connected and undergoing rapid change (FAO 2021). The world's climate is currently changing quickly due to global warming, which is causing, among other things, the melting of polar and glacier ice, sea level rise, acidification of the oceans, changes in the patterns of rainfall and snowfall, more frequent floods and droughts, and an increase in the frequency and intensity of extreme weather events such as tornadoes, hurricanes, and cyclones (DEA 2011a). Over decadal time frames from 1971 to 2010, the average upper ocean temperature has increased globally. This warming is a certainty despite significant uncertainty in yearly averages.

Clues of rapid climate change include: increases in the average global temperature, with the previous decade being the hottest on record; rises in average global sea levels; changes in average rainfall patterns, with some regions experiencing higher rainfall (such as Northern Europe) and other areas experiencing low rainfall (such as the Sahel and southern Africa); and greater climate variability (DEA 2011a). Concerns regarding regional and global sustainable development in the face of a changing climate are raised by the various early repercussions of climate change that are being revealed by international environmental trends because the 400-parts-per-million threshold for atmospheric CO2 has now been crossed (DEA 2016).

Any illusions that the trajectory of global warming has slowed down have been dispelled by the rapid warming, which was heightened by El Nino conditions in 2015 and 2016. The world is already displaying the human and socioeconomic costs of insufficient preparation for climate change impacts by adverse effects, such as lack of rainfall in some regions and excessive rainfall in others, novel diseases, ecosystem damage, crop failures, and heatwaves (DEA 2016).

These are historical temperatures for regions like America, Europe, Asia, and Africa with signs that some parts of these continents have recently seen an unusually high frequency of intense heat waves (IPCC 2013) and other climate-related disasters. These types of climate-related disasters are well recognised for causing civil unrest, forced migration, and even conflict (Besada & Sewankambo 2009; FAO 2021). For example, floods and increased sea levels in western Africa and droughts and the drying up of river basins in southern and eastern Africa have prompted people and groups to migrate in search of new livelihoods. Examples of climate change-related migration in Africa include the ongoing movement of pastoralist communities in northern Kenya that have been devastated by both floods and droughts, as well as rural-urban migration in Ethiopia as a result of unfavourable climatic changes in the highlands (Besada & Sewankambo 2009).

The fourth IPCC Assessment Report predicted that the effects of climate change will differ significantly depending on latitudinal regions and the rate of temperature rise. In some locations, damages from natural disasters, such as water shortages and floods, are anticipated when the temperature rise is less than 1°C (Kim 2012). The report cautions that most places will be vulnerable to natural catastrophe damage if the temperature climbs by 2 to 3°C, and that 20 to 30% of animals and plants will be in danger (Kim 2012). In addition, significant economic and environmental costs, such as ongoing water shortages, ecosystem devastation, decreased food production, and an increase in disease incidence, are anticipated if the temperature rises by more than 3°C (Kim 2012). Even with relatively low average temperature increases, the type, frequency, and severity of extreme events, such as tropical cyclones (including hurricanes and typhoons), floods, droughts, and heavy precipitation events, are predicted to increase as a result of global warming (United Nations Framework Convention on Climate Change [UNFCCC] 2007).

Examining forecasts of globally averaged numbers highlights the uncertainty associated with climate change over the next 100 years. The range of the warming of the global mean temperature in 2100 (relative to 1990) is 1.4–5.8°C, and the degree of uncertainty in the global mean temperature caused by the uncertainty in the emission scenario is roughly equivalent to that caused by the uncertainty in the response of the climate model (Collins & Senior 2002). The sea level is anticipated to rise between 0.18 and 0.59 metres by 2100 (UNFCCC 2007). To put these changes in perspective, the average global temperature has changed by about 5°C since the end of the last ice age. The expected rate of warming is probably unprecedented in the last 10,000 years in addition to the scale of the shift (Collins & Senior 2002).

There is a need for global climate models (GCMs) as primary instruments to determine the causes of historical change and for predicting the long-term future. Global average atmospheric CO2 concentrations rose from 278 to 390.5 ppm in 2011 due to the release of CO2 from industrial and agricultural activities since roughly 1750 (IPCC 2013). Due to an over-reliance on fossil fuels for energy, the atmospheric CO2 concentration is currently higher than it has been for at least the last 800,000 years, and it is predicted to keep increasing (IPCC 2013). Climate change projections depend on future levels of atmospheric GHG emissions which, in turn, are highly reliant on societal behaviour and policy decisions, such as whether we continue to rely on fossil fuels or move to renewable energy sources. The climate is simulated by GCMs under many emission scenarios, each of which represents a potential future (DEA 2017b).

Regional traits, socioeconomic considerations, and climatic variables all have an impact on global climate change that can be predicted by creating a number of plausible scenarios (Kim 2012). Depending on the scenario, estimates of future climate change can differ greatly. The Asian Development Bank Institute (2012) estimates that global agricultural productivity may decline by around 3% with the carbon fertilisation effect and by about 16% if the carbon fertilisation effect did not occur by the 2080s. These losses would be disproportionately concentrated in developing countries, which would suffer losses of 9% with the carbon fertilisation effect and 21% without the carbon fertilisation effect, compared to an 8% gain (with the carbon fertilisation effect) and a 6% loss (without the carbon fertilisation effect) in industrial countries (Asian Development Bank 2012). According to the comprehensive predictions by nation and region, South Asia and Africa would be the two regions most impacted by climate change. Climate change would also have a severe impact on agriculture in Southeast Asia, with damages ranging from 15.1% in Vietnam to 26.2% in Thailand if the trend continues (Asian Development Bank Institute 2012).

2.4 Drivers of anthropogenic climate change

To establish effective mitigation and adaptation measures for smallholder farmers, this research conducted a literature review on drivers of anthropogenic climate change to understand what the human causes (particularly farmers) to climate change are and what drives the causes, how the impacts from the drivers affect us and how to lessen the impact caused by the drivers. Humans contribute to GHG emissions through energy production, transport and other sectors, but there is limited research on how farmers contribute to climate change. This study expands the available literature by documenting how unsustainable agriculture contributes to climate change and highlighting the consequences thereof.

Since the 18th century, scientists have been increasingly concerned about anthropogenic (human-caused) climate change and global warming, prompting the United Nations to establish the IPCC in 1988 to address this growing scientific data. (Headrick 2019). Since 1990, Assessment Reports to convey the climate change problem to help governments slow down and minimise global warming have been published (Headrick 2019).

Abeydeera (2019) argues that human activities, such as the combustion of fuel for power plants and automobiles, cause climate change, leading to an ecological imbalance, global warming, and technological, financial, and social problems as a result of massive amounts of carbon dioxide released into the atmosphere. In addition, deforestation, waste and agricultural activities are also sources of climate change caused by human activities (Ateeq-Ur-Rehman et al 2018:31). Furthermore, industrial processes, such as construction, are also significant contributors of carbon emissions.

Despite all problems caused by climate change, the (World Meteorological Organization 2023) reports that CO_2 emissions from fossil fuels have steadily increased for the past 30 years but the land sector remains a net supplier globally. In addition, the latest IPCC (2023) report indicates that climate change is accelerating and having a greater impact than previously thought. The ocean and land-based sinks, including forests, absorb around 55% of human-caused CO_2 emissions. Methane (CH_4) contributes to approximately 16% of Long-lived greenhouse gas (LLGHG)s' radiative forcing. Natural sources (such as wetlands and termites) emit 40% of methane, whereas anthropogenic sources (such as ruminants, rice agriculture, fossil fuel exploitation, landfills, and biomass burning) provide 60% (WMO 2023). Emissions from agriculture, garbage, and fossil fuels have led to decadal atmospheric rise, with natural emissions from wetlands also playing a role. CH_4 emissions from agriculture and garbage account for 61% of the global methane (WMO 2023). This is a true reflection of land pressure caused by human activity. However, there is a need to understand that anthropogenic climate change is not driven intentionally; there are key drivers that force individuals to participate in unsustainable behaviours, notably in the agriculture sector.

South Africa experienced a rise in greenhouse gas (GHG) emissions, which then declined between 2000 and 2009. Though the country has 20% less GHG emissions than in 2009, 2020's GHG emissions of 442 Mt CO_2 reflect a small decline of 0.8% from 2000 (StatsSA 2023). From 10.22 Mt in 2000 to 7.42 Mt in 2020, per capita CO_2 emissions have reduced. Between 2000 and 2020, the energy supply's intensity declined by 32.3% while the economy's carbon intensity decreased consistently by 40.1% (Stats SA 2023). This is a huge progress achieved by the nation. The country's transition to a low-carbon economy is progressing with the energy sector reducing carbon emissions. The decrease has a tremendous impact on GHG emissions.

Despite the decrease in South Africa’s carbon emissions (StatsSA 2023), like other countries, particularly emerging ones, the country still contributes to GHG emissions. The overall carbon dioxide emissions of the country are calculated using emissions from the provinces. Coal-fired power stations, which generate about 90% of the country's electricity, are the single largest source of GHG emissions in South Africa (Limpopo Economic Development Agency [LEDA] 2020).

Coal-fired power plants not only contribute to climate change, but they are also vulnerable to its effects and repercussions. The table below shows that power generation accounts for more than 80% of carbon dioxide emissions in Limpopo due to the fact that sectors in South Africa, including manufacturing, transportation, agriculture, and others, rely on electricity derived from fossil fuels (DEA 2013). AFOLU Agriculture, forestry and other land use (AFOLU) activities are also thought to contribute to GHG emissions, but to a lesser extent than power generation. Brickworks from cement manufacturers emit 0.3% of carbon dioxide. Although solid waste and household wood are cited as contributors, data on the percentage of emissions are lacking. This is because solid waste is a CH4 from landfill sites. Arndt, Chinowsky, Robinson, Strezepek, Tarp and Thurlow (2012:371) recommend the implementation of policies intended to reduce future GHG emissions.

Table 2.1: Estimated $C0^2$eq emissions in Limpopo

Source of emissions	**$C0^2$ (eq) tpa**	**%Total**
Power generation (excluding Medupi)	25,000,000	82%
Small boilers	1,564,928	5.1%
Liquid fuels	1,229,001	4%
Agriculture game	951,176	3.1%
Biomass (veld fires)	715,367	2.3%
Traffic	578,214	1.9%
Sanitation	178,964	0.6%
Agricultural small stock	126,865	0.4%
Brickworks	82,309	0.3%
Fertiliser manufacturing	43,305	0.1%
Solid waste	-	-
Residential wood/coal	-	-
Estimated total in Limpopo	30,470,130	

(Source: Limpopo Department of Economic Development, Environment and Tourism, LEDET 2016)

Limpopo's carbon dioxide emissions are depicted in the table above.

This predicts an uncertain future for those who rely directly or indirectly on agriculture, particularly rain-fed agriculture, for their livelihoods and have few assets or methods to deal with the changes to come (Mushore et al 2021).

2.4.1 Population growth and land degradation

The industrial revolution is the source of human activities that contributed to the GHG emissions (United Nations Development Programme 2009:10; UNFCCC 2006:6).

Nisbert (2014) believes that pressures of industrialisation and capitalism have contributed to the corruption of nature. The Population Institute (2023) points out that the global population surpassed eight billion individuals in 2022 and is expected to continue rising this century. In South Africa, the current population is 60.6 million (StatsSA 2023) and is estimated to rise to 73 million by 2050 (National Agricultural Marketing Council 2018).

Swim, Clayton and Howard (2011:254) note that an increase in population results in an increase in the demand for services, such as electricity, construction of houses, energy and agriculture (Khan 2017:35). Population increase puts pressure on the agriculture, forestry and fisheries sectors to produce food, feed and fibres as well as revenue and jobs, including ecosystem activities (FAO 2019). These sectors will also be expected to adapt to the challenge of climate change. In southern Africa, there is a significant food demand-supply imbalance, which is expected to increase due to a rise in population and economic development (Von Maltitz, Midley, Veitch, Brúmmer, Rötter, Viehberg & Verste 2024). The reason for food imbalance is land degradation caused by the regular occurrence of climatic events, which deteriorate land and make soil unproductive.

Land degradation is the deprivation and deterioration of the environment, which lessens its capacity to carry out the natural function of life (AbdelRahman 2023). For example, damaged land leads soil to become infertile, resulting in decreased food production. Land degradation is caused by several processes that degrade land usage, both directly and indirectly. Urbanisation, infrastructural development, alien invasive species, bush encroachment, topography, climate, soil erodibility, pests and diseases, and unsustainable land management, poverty, land tenure and access to extension services have been identified as direct drivers of land degradation (DFFE 2018). These drivers make the soil prone to wind and water erosion.

Furthermore, the problem of land degradation is due to water scarcity as it depletes water sources, such as rivers and ground water, and increases soil and wind erosion. In addition, soil erosion and land degradation are significant threats globally. The depletion of water and land resources affect many rural populations, particularly the impoverished, because they rely largely on productive land and rich soil for food and sustainable livelihoods (DFFE 2018). The GHGs are the reason for the depletion of resources as they contribute to rising temperatures leading to farmers being exposed to climatic shocks.

The livelihoods of rural populations rely on natural resources but productive land is becoming increasingly rare due to degraded land that affects agriculture, which is the source of livelihood in many rural communities, negatively. The expansion of agricultural land has contributed significantly to climate change as CO2 is emitted as a GHG in the atmosphere. As a result, anthropogenic climate change has a detrimental impact on food and water security, human health, the economy, society, and ecology, causing losses and damage (IPCC 2023).

Rapid population expansion can lead to increased vulnerability at the household, community, and national levels due to rising human requirements and harsh weather and water conditions in a warming planet (Population Institute 2023). Some of these human needs include housing, food, water, and energy, all of which depend around land. As a result, fast population growth may impede efforts to build resilience and adaptive capabilities since it increases the demand for land, resulting in the degradation of natural resources. The region's small-scale farmers have a varied range of resources, including land and water. To prevent future social upheaval, land use regulations and management must address significant yield gaps, food poverty, and decreasing land ownership (Feil, Reimund, Rötter, Bakhsh, Nelson, Dalheimer, Lam, Ferreira, Odhiambo, Bracho-Mujica, Abdulai, Hoffmann, Bruemmer, & Ayisi 2024).

2.4.2 Agriculture, deforestation and mining

Agriculture is the source of livelihood for many poor people in Africa and South Africa. Hence agriculture and the global food system are large contributors to global GHG emissions, particularly CH4 and N2O (Lynch, Cain, Frame & Pierrehumbert 2021). Grossi, Goglio, Vitali and Williams (2019) state that farmers need agricultural inputs and machinery for feed production. In addition, farmers need access to resources, such as farm machinery, to plough their fields, produce and transport fertilisers and chemicals, and for irrigation, harvesting and threshing of crops but the growing use of nitrogenous fertiliser for the cultivation of high nitrogen-consuming crops has increased nitrous oxide emissions (Kant 2009).

Agriculture and food production are linked to all three of these gases with C02 included, although direct agricultural emissions are exceptional in that CH4 and N2O dominate (Lynch et al 2021). A limited amount of CO2 emissions arises directly from agricultural output as a result of the use of urea and lime; however, these sources account for a very minor part of total CO2 emissions. Holowitz and Gottlieb (2010) maintain that farmers who apply nitrogen fertilisers and manure to their fields can cut emissions by changing their nutrient management techniques. Lynch et al (2021) identified CO2 emissions occurring from agricultural operations such as tractor fuel or inputs such as fertiliser manufacture and transport on farms.

As much as pesticides increase agricultural production, it is noted by Khwidzhili and Worth (2016) that pesticide residues also pollute drinking water, harm food for human consumption, and create negative health effects for farm workers. It is further highlighted that some pesticides can be converted to ozone-depleting gases. Excessive fertiliser use in the long run may alter soil fertility and pH, reducing agricultural output. These fertilisers contain chemicals that are hazardous to the skin and respiratory system. Crop burns can also occur as a result of incorrect fertiliser application (Khwidzhili & Worth 2016).

Apart from crop activities, FAO (2020) point out that livestock production account for two-thirds of GHGs emissions to the total contributed by agriculture sector. In 2018, CH4 emissions from enteric fermentation in the digestive tracts of ruminant animals remained the single greatest component of farm-gate emissions (2.1GtCO2eq).

The rise in livestock numbers drove higher emissions from manure and enteric fermentation by 20% and 13%, respectively, in 2018 compared to 2000 (FAO 2020). Furthermore, emissions from rice agriculture, manure management techniques, and drained organic soils increased by around 7% from 2000 to 2018 (FAO 2020). Farmers are under pressure to feed rising populations, which causes both livestock and crop production to increase.

Other agricultural activities are the burning of crop residues (DAFF 2015; Nwankwoala 2015:227) which is part of clearing the crop fields and the preparation for the planting of other crops (FAO 2015:40). The burning of crop residue could also lead to wind and soil erosion, and veld fires if not managed properly. During harvest times, agricultural waste is produced each year, including sugarcane leaves and tops, woody stalks, and cereal straws (Jain, Bhatia & Pathak 2014). Large amounts of residues are also produced during the milling process used to process farm products. These leftovers may be used as industrial fuel, personal cooking fuel, animal fodder, and thatching for rural dwellings. But a significant amount of the crop waste is not used and is instead abandoned in the fields (Jain et al 2014). Farmers choose burning because it is a quick and simple approach to deal with the massive amounts of crop residues and to get the field ready for the following crop. Burning crop leftovers also depletes resources, damages nutrients, and pollutes the air (Jain et al 2014).

To eliminate these emissions, plant tissue analysis, soil analysis, precision application, the use of slow-release fertilisers or nitrification inhibitors, and timing adjustments to better match plant nutrient uptake are practices that assist farmers in decreasing nitrogen applications without reducing yields (Smith et al 2008).

Lynch et al (2021) suggest that farmers increase operational efficiency or implement farming practices, such as no-till, that need less fuel to lower their emissions of GHGs derived from fossil fuels. Farmers employ measures that enhance the amount of organic matter stored in the soil and the number of agricultural residues left on the field to promote carbon sequestration. These techniques include changing from conventional tillage to conservation tillage or no-till, reducing fallow as part of deliberate crop rotations, switching from annual to perennial crops, and boosting field residues through irrigation, fertilisation, planting hay or cover crops, or adding more organic material, like manure.

Holowitz and Gottlieb (2010) suggest that changing livestock feeds can help livestock management reduce methane emissions. Dairy and hog producers can construct digesters to absorb methane produced during manure storage; the captured methane can then be used to make electricity. Digesters cut emissions by converting methane emissions from alternative means of manure disposal into less potent CO2 and generate energy that replaces CO2 emissions from fossil fuel-based electricity. Farmers can contribute to the energy scarcity by energy diversity. Renewable energy can be a conservation action. Biogas, produced from livestock manure, organic waste from homes, businesses, and industries, is one type of renewable energy (Susilawati & Pramono 2021).

In recent decades, there has been an unsustainable trend of deforestation (Rötter, Nkomo, zu Dewers & Veste 2024) caused by anthropogenic climate change due to the rise in population growth and economic activities. For example, an increase in population results in an increase in the demand for services such as electricity and construction of houses (Department of Energy [DE] 2012; LEDET 2016:5). Fuel wood, charcoal, agricultural expansion, and bush fires are the most common causes of deforestation (Ndamani & Watanabe 2015:4598) leading to degraded land.

Tree cutting or deforestation is a contributing factor to fossil fuel emissions and changes in land use, hence, farmers are expected to reduce their own carbon dioxide emissions by moving to no tilling in crop management (IPCC 2001). People in rural areas use wood for different purposes such as cooking and building houses (Nwankwoalo 2015). The FAO (2015) argues that forests play a vital role in addressing climate change by absorbing carbon dioxide from the atmosphere. For example, collecting wood by many people in rural areas (Khan 2017) could result in droughts and floods in those areas (Nwankwoala 2015).

Another sector contributing to GHG emissions is mining, which is a source of wealth in South Africa, but it also harms the soil and underlying structure by creating chemicals that contaminate soil and waterways, causing land degradation. The DFFE (2018) reported that current mines will occupy 326,000 ha of agricultural land, while another 439 000 ha is under exploration. Despite careful restoration processes, land capacity declines from pre- to post-mining. These human activities have contributed to the rising of temperatures resulting in projections of climate change in the future.

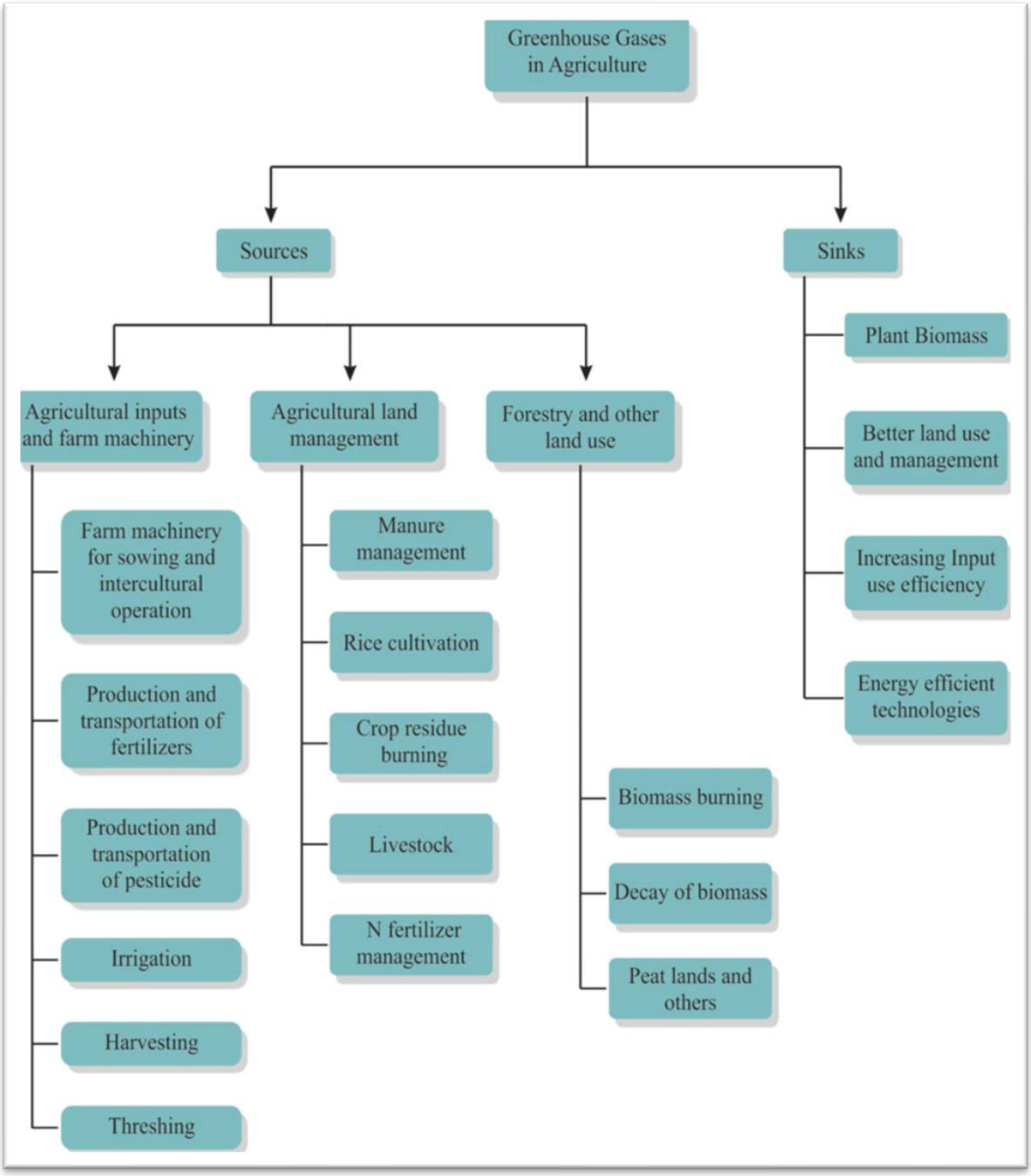


Figure 2:2 Schematic presentation of sources and sinks of GHGs in agriculture, forestry, and other land use (AFOLU)

2.5 South African climate change projections

Considering that the effects of climate change are already being felt throughout the continent, it is becoming common to utilise climate forecasts as a tool to guide decision-making in a variety of fields, such as biodiversity preservation and sustainable development, which includes preserving the livelihoods of populations that depend on ecosystem services (Janes, Jones & Hartley 2015). With the current climate variability, climate change projections may assist decision makers to foresee long-term changes and establish plans to adapt to future changes. Decision makers will therefore better understand how to address future anthropogenic climate changes.

Climate change has a significant impact on South Africa, particularly in terms of increased temperatures and rainfall variability. The country warmed dramatically between 1931 and 2015 at a rate of 2°C or perhaps more each century. The Western and Northern Cape, as well as the north-eastern provinces of Limpopo and Mpumalanga, have seen the most warming, with the region's effects spreading southward to KwaZulu-Natal's coastal regions (DEA 2017a). Additionally, increases have been seen, not just in the seasonal and annual mean minimum and maximum temperatures, but also in their extremes. Particularly, the Western and Northern Cape, Gauteng, Limpopo, and eastern KwaZulu-Natal have been warming at a rate that is more than twice the rate of global warming (DEA 2017a). Understanding these climate projections and impacts is critical in climate change adaptation (DEA 2017b) to protect livelihoods of the poor through informed decisions.

Studies of historical temperature trends show that South Africa warmed significantly between 1931 and 2015 (DEA 2017a). Predicted scenarios in South Africa indicate an increased mean yearly temperatures of 2.5 to 3.5°C, less rain, and different seasonal patterns on the arid Karoo edge by the middle of the century (Mazwamuse 2010). Reduced precipitation and increased temperatures will have an influence on the production of fodder and raise the marginal cost of grazing (Mazwamuse 2010) and production of agricultural crops.

Strong evidence points to statistically significant increases in rainfall over the southern interior areas from 1921 to 2015, stretching from the western and eastern interiors of the Western and Eastern Cape Provinces northward to the central interior region of the Northern Cape (DEA 2017a). Over these areas, extreme daily rainfall occurrences have also increased, and these increases have now reached the Free State, Gauteng, and Northwest Provinces to the north. There is convincing evidence of statistically significant reductions in annual rainfall totals over Limpopo (DEA 2017a). The fact that temperatures will rise significantly over the next 60 years is a critical aspect of South Africa's projected climate change forecasts. For the entirety of southern Africa, a drastic warming of more than 4°C is predicted.

By mid-century, it has been estimated that the South African coast will warm by between 1 and 2°C and the interior by about 2 to 3°C, even under emission scenarios that are more cautious than the present international emission trends (DEA 2011a). Warming is expected to reach 3 to 4°C at the coast and 6 to 7°C inland by 2100 (DEA 2011a). Life will drastically change as a result of such temperature increases since the country will become significantly drier in some areas and less water will be available nationwide due to increased evaporation (DEA 2011a).

Annual temperature increases are predicted to range from 1.5 to 2.5°C along the coast to 3.0 to 3.5°C in the distant interior in the intermediate future (DAFF 2015) due to influence from oceans. With forecast increases between 3.0 and 5.0°C along the coast and up to 6.0°C and more in the interior, temperatures begin to accelerate by the end of the century (DAFF 2015). The country's annual temperature variations tend to be higher in the north and lower in the south from year to year. The median number of extreme heat waves is expected to more than double in the near future (DAFF 2015), with the most impacted regions being those that are currently hot, specifically, South Africa's eastern, northern, and Northern Cape boundaries. The average yearly rise in heat units, on the other hand, is expected to range from 10% along the coast (where temperatures are influenced by marine factors) to > 30% in the interior in the intermediate future. Heat units are crucial for both crop growth and insect life cycles (DAFF 2015).

The projected increases for the summer season are more moderate, but still quite high in ecologically sensitive mountainous regions, whereas the projected increases for the winter season are noticeably higher, averaging > 30% across most of South Africa and exceeding doubling in some locations in the Maluti and Drakensberg Mountain ranges (DAFF 2015). The normal processes of ice creation and melting are changed by this temperature increase, along with the hydrological cycles and the air and ocean currents. Consequently, social, biological, and ecological systems are also impacted, and there is a serious threat to the availability of food, health, and water resources, as well as to economic growth (LEDET 2016).

The average temperature in South Africa has risen by 1.5°C during the past 50 years, which is 1.5°C higher than the observed global average (DEA 2011a). Almost everywhere in the country, notably during the fall months, maximum and minimum temperatures have risen, while rainfall has displayed considerable inter-annual variability and fewer rain days (DEA 2013). These forecasted variations in precipitation and temperature have the potential to impact on the environment, society, and economy either directly or indirectly (LEDET 2015). The forecast that a significant decrease in rainfall in the summer rainfall zone can be anticipated in the range of 5% to 10% is of great concern for South Africa as a semi-arid nation (DEAT 2004). Along with these predictions, there will be a rise in the frequency of both droughts and floods, with extended dry spells being followed by powerful storms. According to the World Bank Group (2021), the likelihood of flooding in the future is also anticipated to rise throughout the country, but especially in KwaZulu-Natal, the Eastern Cape, and Limpopo.

The annual rainfall trends in a study conducted in South Africa from 1921 to 2015 indicate a positive trend in annual rainfall totals over the central southern region, which extends somewhat to the north. In the northern regions of the Limpopo Province, rainfall trends were negative (DEAT 2004). The study also indicated that the declining trends in autumn rainfall account for the declining trends in annual rainfall across Limpopo (DEA 2017a). LEDET (2016) envisages that the Limpopo Province region may experience temperature increases of up to 2°C by 2035, 1-2°C between 2040 and 2060 (or even 2-5°C in the high-end scenarios), and 3-6°C between 2080 and 2100 (or even 4-7°C in the high-end scenarios).

2.5.1 Climate change projections in Limpopo

Table 2.2: Climate change projections in Limpopo

Limpopo	Thunderstorms, hailstorms, excessive rainfall and flooding, droughts, fires and outbreaks of diseases	• Increase in average temperature of 1–2°C in the near future • Increased annual number of very hot days to 20 days in the south and 50 days in the Limpopo valley in the north • Decrease in rainfall • Increases and decreases in the frequency of extreme weather events • Wet years are likely to occur less frequently • Possible increase in the number of wet years for the Limpopo valley • Dry years to occur more often

(Source: Report for the local government SETA: 2014)

Table 2.2 displays some climate change forecasts for Limpopo. The average temperature is expected to rise by 1 to 2°C in the near future, according to estimates. The expected temperature increases in Limpopo are likely to cause thunderstorms, hailstorms, excessive rainfall and flooding, droughts, fires, and disease outbreaks. Drought and floods are the most common disasters in Limpopo causing damage to crops and killing livestock (Afful & Ayisi 2018). Long-term drought had a significant influence on Limpopo Province's agricultural industry, with rain-fed agriculture suffering the most. The number of yearly hot days will rise as the average temperature rises. The decrease in rainfall will be exacerbated by the increase in temperature. Limpopo will also see a rise and decline in the frequency of extreme weather events caused by high temperatures. Dry years are projected to occur more frequently, whereas rainy years are expected to occur less frequently.

Other climate change consequences include decreased rainfall reliability as the current view of long-term changes in precipitation is that Limpopo Province is becoming drier and that there is a pronounced decrease in rainfall, altered climatic variations, and frequency of droughts. Effective production adaptation techniques are necessary for agricultural producers in the Limpopo Province to lessen their vulnerability (productivity and food security) to the adverse consequences of climate change and uncertainty (Afful & Ayisi 2018).

As a result, agriculture production suffers due to water deficits (Maponya & Mpandeli 2012:50). As a result, there is disruption of the agricultural calendar, a decrease in agricultural production and the introduction of pests, among others (Yaméogo, Fonta & Wünscher 2018). Countries encountering a decline in agricultural productivity due to climate change envisage increasing importing agricultural products (FAO 2018:20). Mpandeli, Nesamvuni and Maponya (2015) emphasise that drought poses a serious challenge to both smallholder farmers and commercial farmers in Limpopo Province. The worst drought in Limpopo was from the 1970s up to 2012 (Maponya & Mpandeli 2013).

The evidence above shows that climate change can bring negative or positive impacts. Moser and Ekstrom (2010:2) believe that communities need to prepare or adapt to unavoidable climate change impacts. Therefore, for sustainable agricultural development, adaptation strategies should be planned to maximise opportunities and minimise costs.

2.6 Development of climate change adaptation strategies

Reports from IPCC, UNFCCC conventions, Conference of Parties (COP) 16 in Cancun, COP 21 in Paris and the increase in extreme climatic hazards globally, including in South Africa, show the reasons for the development of climate change adaptation strategies. To respond to climate change, it is important for decision makers to develop plans or strategies to integrate climate change adaptation and mitigation into national plans and policies. At a global level, the UNFCCC was introduced in 1994 (DAFF 2013; Glavovic & Smith 2014) with the aim of committing all member countries to work collaboratively by developing and implementing plans to mitigate and adapt to the impacts of climate change (UNFCCC 2007; DAFF 2013).

Despite agreement with the UNFCCC, signatory countries recognised the importance of achieving a global peak in GHG emissions as soon as possible, based on existing knowledge (UNFCCC 2020).

These signatory countries committed to describing their planned efforts to reduce national emissions, including voluntary emission reduction promises, and adapt to the effects of climate change through the Nationally Determined Contributions (NDCs). The UNFCCC further commits all signatories to formulate, implement, publish and update adaptation measures, cooperate on adaptation, and mandates developed countries to provide international climate funds to developing countries (Climate Transparency 2018:9). The financial mechanism that was introduced by the UNFCCC in order to provide climate funds to support the implementation of the Paris Agreement is called the Green Climate Fund (GCF).

To realise the implementation of countries' commitments with the UNFCCC, the Conference of Parties (COP) 16 adopted the Cancun Adaptation Framework in 2010 that guides poor nations in creating National Adaptation Plans (NAPs). The reason for developing plans is to lessen their vulnerability to the effects of climate change and promote adaptation or resilience (DEFF 2019) to the same level as mitigation (DFFE 2020). The 2010 Conference of Parties (COP) further allowed poor nations to identify medium- and long-term adaptation needs and develop strategies to address them (UNFCCC 2023). The NAPs outline the process and plans for ongoing support, with the goal of generating improved NAPs in the future (UNFCCC 2023). The NCCAS is a ten-year plan, evaluated every five years.

Planning for climate change helps South Africa to better position itself internationally and grasp opportunities presented by changing weather patterns (DEFF 2019). The Climate Change Bill at country level also mandates the development and assessment of a national adaptation plan every five years, and that the nation's adaptation response be guided by national adaptation objectives (Council for Scientific and Industrial Research [CSIR] 2021). The plan promotes joint efforts to reduce the risk of investing in activities that may not be complementary (DEA 2016). The strategy is necessary to strengthen resilience, mitigate negative consequences, and promote positive changes for sustainable development (DEA 2016). Moreover, the DFFE (2020) identified the importance of developing NAS as follows: (a) NAS guides serve as a point of departure for resource allocation to climate change adaptation; (b) NAS identifies priority areas for adaptation response in South Africa; (c) NAS supports South Africa in meeting its international climate obligations; (d) NAS further serves as the cornerstone for the nation's response to climate change and to reflect a united coherent, cross-sectoral, and economy-wide approach to adaptation (Ngwenya 2017).

In accordance with Article 7.9 of the Paris Agreement and the UNFCCC, South Africa has committed to its responsibilities, and the NCCAS serves as the country's national adaptation strategy. Furthermore, the agreement includes South Africa's first Nationally Determined Contributions (NDC), a policy framework that allows the country to set its national climate change adaptation targets and provide broad guidance to all economic sectors in carrying out adaptation efforts (RSA 2021).

The Nationally Determined Contributions set six major targets for climate change adaptation (DEA 2016): (1) create a nationwide adaption plan; (2) integrate climate issues into national, provincial, and municipal government frameworks and sectoral programmes; (3) increase the capacity of institutions for response formulation and execution; (4) set up a rapid detection, vulnerability, and adaptability observing system; (5) create a vulnerability evaluation and adaptation strategies framework; and (6) share the past investments in adaptability.

In South Africa, the National Climate Change Adaptation Strategy (NCCAS) (DEA 2017a) includes the following strategic goals that have been approved by the Cabinet (CSIR 2021): strategic goal 1: Improving the understanding of the impacts of climate change and the ability to respond to it; strategic goal 2: Developing systems and resources for the efficient implementation of climate change responses; strategic goal 3: Strengthening climate resilience and adaptive capacity; and strategic goal 4: Including climate change adaptation in development objectives, policy, planning, and execution.

The adaptation to climate change in South Africa is strengthened through initiatives at national, provincial and local levels, in several sectors and in civil society (DEA 2016:19). These initiatives include the development of policies, programmes and projects. The World Bank Group (2021) believes that these initiatives are aimed at preparing and improving institutional frameworks for managing the consequences of climate change to make the resources needed to support strategic adaptation efforts and to enhance low-emission and climate-resilient development.

Leading the NAP process, coordination and management at national level in South Africa is the former Department of Environmental Affairs (DEA), working with other departments such as cooperative governance, human settlements, water and sanitation, agriculture, forestry, and fisheries, health, energy, transportation, and public works (DEFF 2019). At the provincial level, provincial environmental departments lead and coordinate climate responses with other provincial institutions with the help of sectors in national departments. At municipal level, climate change is being integrated with municipal disaster management strategies in Integrated Development Plans (IDPs) with the help of DEFF and SALGA (DEA 2017a).

For implementing NAS, sector plans that address climate change and the country's development needs are linked to the Medium Term Strategic Framework, a five-year plan drawn up by the national government to achieve its goals. The MTSF presents a number of outcomes for line departments to pursue. For example, outcome 10 of the 2019-2024 MTSF emphasises the target to implement climate change (DEA 2017a). Thus, government sectoral strategies conform with the NDP while additionally backing short-term initiatives to safeguard the environment from climate change (CSIR 2021).

2.7 Climate risks and impacts

Extreme weather events and drastically changing weather patterns affect food security, health, water, and energy security which, in turn, hinders Africa's ability to expand and develop (Besada & Sewankambo 2009:9). These events are devastating as about three-quarters of Africa's population rely on rain-fed agriculture for their livelihoods. Because of these events, crop failure, reduced agricultural yields, and threats to rural and pastoralist populations are all effects of droughts, floods, and the loss of arable land due to desertification and soil erosion (Besada & Sewankambo 2009).

The FAO (2018) states that disasters have a negative impact on the forestry industry as well as the development of crops, the health of cattle, the productivity of fisheries, and aquaculture. When they occur during specific periods of the plant's life cycle, droughts reduce yields because they produce long-term water shortages and significant heat stress in crops (FAO 2018). For instance, hot temperatures resulting in either drought or floods in Mali are the main reasons for reduction of agricultural productivity (World Bank Group 2011a). The AfDB (2018) believes that hot temperatures stress the water resources that could result in decreased crop yields. According to Ousmane (2021), these hot temperatures are the results of wood used as a source of heat by some households in Mali. This could have a serious negative impact on food security as Ousmane (2021) indicated that the population growth in Mali is increasing.

Climate change is predicted to have a direct impact on almost all sectors, particularly through damaging extreme weather events in the short term, disruptions in water and food security in the medium to long term, negative effects on human settlements and human health in the short to medium term, and ecological and biodiversity impacts in the medium to long term (DEA 2016). Climate change impacts are likely to raise the risks of crop failure, especially for climate-sensitive or marginal crops like maize and horticultural/vegetable crops (Hunter, Crespo, Coldrey, Cronin & New 2020).

The other impacts faced by smallholder farmers in South Africa that are exacerbated by climate change are high agricultural input costs and transport costs (Oluwatayo 2019). Additionally, the higher average temperatures may result in more frequent or intense heat waves and abnormally hot days, which may increase water loss through evapotranspiration and stress on crops (Hunter et al 2020). Also, a negative impact of climate change is the high mortality rate of animals due to a lack of feed (Zwane & Montmasson-Clair 2016) caused by extreme whether events and a lack of water as a result of long severe droughts.

Droughts, floods, pests that attack crops are the problems brought by climate change. These risks impede development and food security, and a changing climate is projected to make them more intense and frequent (World Bank Group 2011a). Droughts decrease the quantity and quality of crops, and farmers’ income (Kusumasari 2016). When agricultural production, livestock, and fish supplies decrease, hungry and malnourished people, particularly children, the elderly, and the unwell, suffer (Zhu et al 2011).

2.7.1 Climate change impacts in Limpopo Province

Table 2.3: Direct and indirect effects of climate change on the Limpopo environment and society

Sector	**Climate change effects**
Water	• Decrease in summer rainfall • Low/high river flows are anticipated to decrease leading to water shortages • Increased evapotranspiration (potential evaporation of about 5% per 1°C) and decreased soil moisture • Reduced recharge of rain and falling water levels in boreholes • Flooding, contamination of available water and droughts
Agriculture	• Decreased productivity of food crops • Increased crop irrigation requirements due to increased temperature • Decreased soil moisture levels as a result of changed runoff patterns • Crops grown on marginal land will have to contend with land degradation and reduced soil productivity • Crop and livestock production could be adversely affected by changes in the distributions of diseases, pests and insects • High vulnerability of certain agricultural crops due to decreased water availability and increased temperature
Biodiversity	• Increased heat stress on plants, animals and humans • Changing ecosystems leading to species shifts and extinction • Increased alien vegetation and increased risk of wildfires
Social	• Food security • Health impacts will arise or worsen due to climate stresses, and climate shocks • Damage to livelihoods

(Source: DEA 2016)

The occurrence of extreme climatic events will grow as weather patterns fluctuate. Climate change is impacting sectors like water, agriculture, biodiversity and social sectors. Climate change and variability may have significant consequences in locations like Limpopo Province, where 57% of the population is involved in agricultural production and just 25% of farmers irrigate (Afful & Ayisi 2018). The DEA (2013, 2015) is concerned with the water shortages in South Africa and that South Africa, including Limpopo, received warmer temperatures. Rising temperatures lead to drought which, in turn, results in more water shortages and a greater need for irrigation (Pathak, Aggarwal & Singh 2012). Maponya and Mpadeli (2013) and Mpandeli, Nesamvuni and Maponya (2015) agree that Limpopo Province is prone to drought due to climate change. Table 2.3 shows that high temperatures decrease summer rainfall and increase evapotranspiration and soil moisture leading to droughts and floods which impact on the river flows leading to water shortages and food insecurity. In addition, the land becomes less productive due to drought making it difficult for smallholder farmers to produce enough food (Zhu et al 2011:10).

Heat from high temperatures is likely to harm plants, animals, and humans, resulting in wildfires that damage biodiversity and cause food shortages. Other species may become lost as a result of climate change, while others, such as animals, may migrate to new locations. Veldfires may be caused by human activities such as land deterioration, which destroys people's livelihoods. Aside from food security, humans are anticipated to face health concerns, food instability, and water shortages as a result of climate change. Malaria and cholera are examples of diseases that are expected to affect humans as a result of climate change.

Table 2.4: Current impacts of drought on production

	Severe	**Moderate**	**Minimal effect**
Maize	Severe		
Wheat	Severe		
Oil seeds		Moderate	
Sunflower			Minimal
Soybeans		Moderate	
Groundnuts		Moderate	
Sugar	Severe		
Potatoes		Moderate	
Beef and sheep	Severe		
Poultry		Moderate	
Pork			Minimal
Dairy		Moderate	
Forestry			Minimal
Fruit			Minimal
Citrus		Moderate	
Table grapes			Minimal
Game			Minimal
Wool and Mohair			Minimal
Wine		Moderate	
Cotton		Moderate	
Tobacco		Moderate	
Ostriches			Minimal
Vegetables			Minimal

(Source: Agri SA 2016)

The 1970s, 1980s, 1990s, and more recent droughts (for instance, 2000-2005, 2012) were the worst to hit Limpopo Province's major areas (Maponya & Mpandeli 2013). As drought is recurring, South Africa experienced another drought in 2016 (Agri SA 2016). These droughts had severe impacts on crops such as maize and wheat, and small and large livestock such as sheep and cattle. Some examples of how drought affected commodities, maize and livestock in South Africa was discussed in Chapter 1. To ensure food security, it is critical to discover livestock breeds and maize cultivars that can withstand extreme climate conditions.

Droughts have social and economic impacts for farmers who fail to produce enough food thereby perpetuating the levels of poverty. Furthermore, droughts have moderate effects on commodities such as oil seeds, groundnuts, soyabeans, potatoes, poultry, dairy, cotton, wine and other commodities. On the other hand, climate change has had minimal effects on table grapes, fruits, poultry, ostriches, game, vegetables, wool and mohair. Adaptation is necessary to protect populations, assets, and ecosystems from the risks and repercussions of climate change.

2.8 Forms of climate change adaptation

There are numerous definitions of adaptation in climate change literature. Adaptation to climate change is defined by Feng, Liu, Huo and Ma (2017) as an adjustment to limit the impact of climate change on the farming operation, livelihoods, and people’s lives. The study used Bradshaw et al’s (2004:199) definition that adaptations are those responses by individuals, groups and governments to climatic change or other stimuli that are used to reduce their vulnerability or susceptibility to unfavourable impacts or damage potential.

Adaptation to climate change refers to taking correct actions in reducing the detrimental effects of climate change and making correct adaptation and changes (Akinnagbe & Orohibe 2014:408). Farmers must accept that, due to the changing weather patterns, they need to adapt to climate change (Gbetibouo 2009:1). Agricultural adaptation to climate change is the way in which farmers respond to unpredictable weather patterns. Mugambi (2017:114) maintains that adaptation to climate changes requires both short-term and long-term strategies and that the changes in weather patterns and climate have forced farmers across the globe to make changes to their agricultural activities or other enterprises.

Adaptation to climate change is an urgent matter in developing countries (UNFCCC 2007:29). Farmers in these countries have accumulated experience from previous weather patterns to help them to cope with extreme weather events. As agriculture is directly affected by climate change, adaptation strategies, technologies and practices are becoming increasingly important issues for promoting development.

Adaptation strategies and actions include both short term and longer term strategies (Moser & Ekstrom 2010:22026). However, Adger et al (2004:80) believe that short term adaptation may become unsuccessful in the long term. For example, farmers who drill boreholes to address the challenge of climate change find that, when the water table is low, they will not be able to irrigate their crops therefore this is a temporarily solution. Farmers' responses to climate change effects through adaptation strategies are influenced by their socioeconomic characteristics. This includes the farmers' knowledge and experiences (Uddin et al 2014:226).

Autonomous and planned adaptation are two forms of adaptations. The term "autonomous adaptation" means that individuals or communities can make determined efforts and adapt to environmental risks without any institutional intervention (Forsyth & Evans 2013). Autonomous adaptations are perceived as short-term adjustments since their development and implementation does not require intervention in the form of research or policy (FAO 2007:5). This is the form of adaptation which is practiced by individuals who do not benefit through external incentives but do so for their own benefit (Fan et al 2017:5). Holzkämper (2017) believes that these are short term responses, and they should involve local knowledge and experience in order to address moderate impacts of climate change occurring over a long period of time. It is for this reason that the FAO (2019) believes that farmers who have been practising farming in a particular place have gathered knowledge about the effects of weather and climate on their production systems.

According to Bawakyillenuo, Jaro and Teye (2014:5) and Galdies and Galdies (2016), autonomous responses are those occurring at the farm level, such as improved irrigation, adjustments to tillage practices, crop diversification, changing of the growing calendar, use of heat-, salt- or drought-tolerant crop varieties, or buying insurance (to protect against potential loss). However, the urgency of smallholders to take part in autonomous adaptation is undetermined and not well understood (Forsyth & Evans 2013:7). The FAO (2007:5) gives an example of autonomous adaptation as a farmer who reacts by using different planting dates based on changes in precipitation patterns. Adger, Brooks, Bentham, Agnew and Eriksen (2004:80) argue that, although short term adaptation may be viewed by adopters as a strategy of adaptation, their results may become unsuccessful in the long term.

According to Bawakyillenuo et al (2014:5) and Galdies and Galdies (2016), autonomous responses are those occurring at the farm level, such as improved irrigation, adjustments to tillage practices, crop diversification, changes to the growing calendar, the use of heat-, salt- or drought-tolerant crop varieties and buying insurance (to protect against potential loss). Other examples of adaptations at farm level include changing crop hybrids, the types and varieties of crops, intensification of production, the location of production, irrigation systems, and the timing of farm operations. This includes making use of weather information systems (Belliveau et al 2006:29).

Planned adaptations are generally public interventions (by government, Non-Governmental Organisations [NGOs] and other groups) designed to solve challenges not fully addressed by autonomous actions (Fan et al 2017:5). Planned adaptation is the result of a deliberative policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, to maintain, or to achieve a desired state (Malik et al 2010:4). Holzkämper (2017) defines planned adaptation as long-term responses that require strategic plans from international, regional and national bodies. Füssel (2007:267) contends that the present and future information about climate change is used to find out if it is appropriate for the current and planned practices, policies and infrastructure. According to FAO (2007:5), planned adaptation measures are purposive policy options or response strategies which are developed to improve the adaptive capacity of the agricultural system by defining adaptation options. Planned adaptation can be either reactive, that is, after experiencing some climate change impacts, or proactive, that is, before the occurrence of climate change (Füssel 2007:267). Jones (2010) identifies examples of planned interventions, such as the use of drought resistant crop varieties, to improve the adaptation of early warning systems (flood, veld fire, storms etc.).

2.9 Climate change adaptation at national level

South Africa is experiencing climate change effects that have a negative impact on national development. Therefore, the government of South Africa has developed policies, programmes and projects that give a clear direction on how to address climate change to secure a sustainable country. Governments integrate climate change issues into development planning, budgeting, and implementation in all sectors and at all levels by developing and adopting policies and frameworks to improve adaptive capability and resilience to climate variability and change while also promoting a low-carbon development path.

2.9.1 The Constitution of the Republic of South Africa

Section 24 of the Constitution (108 of 1996) of the Republic of South Africa (SA 1996) stipulates the rights to environment. The environmental clause is provided in Chapter 2 of the Constitution under the Bill of Rights which is as follows:

"Everyone has the right

(a) to an environment that is not harmful to their health or well-being; and

(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:

(i) prevent pollution and ecological degradation.

(ii) promote conservation; and

(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

2.9.2 National Development Plan

The National Planning Commission communicated the long-term National Development Plan (NDP) which is the vision of South Africa and its citizens for the future. In 2012, the NDP: Vision 2030 became the country's road map for economic growth and development. The NDP provides critical factors that will enable South Africa to achieve the objectives of the NDP (SA, Voluntary National Review Report 2019:23). The broad objectives of the NDP are to reduce unemployment, eliminate poverty and reduce inequality. The Report on the GCRF-Africa Participatory Scenarios Workshop 2018 describes the NDP's vision 2030 of climate change as: "… by 2030, South Africa has to reduce its dependency on carbon, natural resources and energy, while balancing this transition with its objectives of increasing employment and reducing inequality."

The NPC believes that South Africa's NDP by 2030 vision on climate change can be attained through the development of long-term adaptation mitigation strategies and policies capable of reacting to the impacts of climate change. The implementation of these policies will contribute to a minimum GHG by producing an environmentally sustainable, climate change resilient, low-carbon and just society through efforts to reduce pollution and emissions and adapt and mitigate the effects of climate change.

The Ratification of Paris Agreement by South Africa in 2016 confirmed its commitment to addressing the impacts of climate change (Department of National Treasury [DNT] 2017). A carbon tax was also implemented from June 2019 which puts a price on GHG emissions, and incentivises people, businesses, and governments to reduce emissions. The objectives are to develop a low-carbon economy and make polluters accountable for their negligence (DNT 2017).

The NDP's steps to ensure that, in 20 years, South Africa's transition to an environmentally sustainable, climate-resilient, low-carbon economy and just society will be well under way and that the country's energy system will look very different to the current situation. Coal will contribute proportionately less to primary-energy needs, while gas and renewable energy resources, especially wind, solar and imported hydroelectricity, will play a much larger role. Public transport will be highly developed and imported hybrid and electric vehicles will be more widely used. Thus, the link can be broken between economic activity on one hand and environmental degradation and carbon-intensive consumption and production patterns on the other while the country remains competitive within the global economy. The National Planning Commission (NPC 2011) has embarked on a process to deepen the initial work in Chapter 5 of the NDP, through engagements and dialogues with the Social Partner on Pathways for a Just Transition.

Chapter Five of the NDP focuses on environmental sustainability and the transition to a low carbon economy. The NPC (2011:179) indicates that South Africa has taken steps in formulating and implementing measures to adapt to and mitigate climate change as the country is a signatory to international laws, namely, the UNFCCC and the Paris Agreement. The country has thereby committed itself to contributing to a reduction of emissions.

The Limpopo Climate Change Response Strategy 2016-2020 outlines some of objectives linked to climate change that the NDP needs to achieve, as follows:

- Achieve the peak, plateau and decline trajectory for GHG emission, with the peak being reached around 2025;
- By 2030, an economy-wide carbon price should be entrenched;
- Carbon price, building standards, vehicle emissions, standards and municipal regulations to achieve scale in stimulating renewable energy, waste recycling and in retrofitting buildings;
- Carbon pricing mechanisms, supported by a wider suite of mitigation policy instruments to drive energy efficiency;
- Zero emission building standards by 2030;
- All new buildings to meet the energy efficiency criteria set out in SANS 204;
- Absolute reductions in the total volume of waste disposed to landfill each year;

- At least 20 000 MW of renewable energy should be contracted by 2030;
- Improved disaster preparedness for extreme climate events;
- Increased investment in new agricultural technologies, research and the development of adaptation strategies for the protection of rural livelihoods and the expansion of commercial agriculture;
- Channel public investment into research, new agricultural technologies for commercial farming as well as for the development of adaptation strategies and support services for small-scale and rural farmers;
- An independent Climate Change Centre in partnership with academia and other appropriate institutions, to be established by government to support the actions of government, business and civil society;
- Put in place a regulatory framework for land use, to ensure conservation and the restoration of protected areas.

Chapter Six of the NDP emphasises the expansion of irrigated land considering the existing water resources and the establishment of water schemes to improve the livelihoods of people through creating one million jobs in agriculture. The plan also outlines that the under-utilised land in communal areas and land reform projects needs to be converted into commercial production. Commercial agricultural sectors with the high potential of growth and employment should be selected and supported (NPC 2012:196; Musvoto et al 2015:18).

2.9.3 National Climate Change Response White Paper

In South Africa, the Department of Environmental Affairs is the focal point for climate action and, as such, is responsible for the development of the policy and legislative context. The department published a National Climate Change Response White Paper in 2011, coordinated the development of Long-Term Adaptation Scenarios in 2015 and is supporting various sector departments in developing sector adaptation plans (DEA 2017a). The purpose of the National Climate Change Response White Paper is to outline the country’s vision of short-term, medium-term and long-term effective climate change responses and of the transition into a lower-carbon economy and society (Musvoto 2015:21).

Musvoto et al (2015) propose that agriculture is one of the solutions to a green economy because many agricultural activities are able to address the challenges faced by humans such as social, economic and environmental problems. According to LEDET (2016), South Africa’s National Climate Change Response has two objectives which are:

- To manage the unavoidable impacts of climate change through implementing emergency responses; and
- To make a fair contribution to the global effort to stabilise GHG concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner.

The NCCRWP developed Near Priority Flagship programmes with the aim of responding to climate change. The flagship programmes focus on action and response to climate change through both mitigation and adaptation imperatives (DEA 2016). The NCCRWP recognises the Flagship Programmes as an integral part of South Africa’s climate change response policy.

2.9.4 South African Climate Change response flagship programmes

The Near-term Priority Flagship Programmes represent the leading actions that are underway in South Africa to advance the country's climate change response efforts (DEA 2016). The programmes include both the expansion of existing climate change initiatives and the launch of new initiatives by 2020. South Africa already has a solid foundation for climate change mitigation and resilience. The Flagship Programmes offer a unified, coherent narrative of South Africa's response to climate change and demonstrate how its ambition, capability, and knowledge have evolved and grown over time. Thus, the Flagship Programmes serve as a constant reminder of South Africa's long-standing commitment to social and economic progress (DEA 2016). The programmes and projects are discussed as follows:

2.9.4.1 Expanded Public Works Flagship Programme

The programme is the extension of the existing Expanded Public Works Programme (EPWP) and includes projects such as Working on Fire, Working for Water, and Working for Energy (DNT 2017:65). This flagship programme protects the environment and uplifts the standard of living of the poor through employment creation. Unemployment and poverty are the biggest challenges faced by South Africa with rural communities being seriously affected (South Africa, Department of Environmental Affairs & Public Works [DEA & PW] 2014). According to Stats SA (2023), the rate of unemployment increased to 34,3% during 2021 and youth unemployment was reported to be at 48,3% during the same year.

The NDP plans to reduce unemployment by 6% and create 11 million jobs by 2030 (DEA & PW 2014:10). The EPWP has been established to ensure that two million jobs are created by 2020 (DEA & PW 2014). Agriculture in South Africa plays a crucial role in terms of economic growth since its contribution is 10% of formal employment (Vink & Kirsten 2001). Agriculture in South Africa sustains livelihood opportunities through the creation of jobs (Okrin & Njobe 2000). Fifty-two percent of people from former homelands residing in rural areas are employed on farms (Okrin & Njobe 2000). To achieve this flagship programme, the following projects need to be implemented:

Working for water

Invasive alien species (Richardson & Van Wilgen 2004:45) have been attacking biodiversity, agricultural land, rivers, catchments and conservation areas (Zimmermann, Moran & Hoffmann 2004:34). Natural capital and economic productivity have been destroyed by these invasive species. A campaign was held in South Africa to raise awareness and provide education about invasive alien species and strategies on how to control these species (Magadlela & Mdzeke 2004:96).

Working for Water is a programme designed to protect the environment by clearing alien plants to alleviate poverty (Magadlela 2001), provide employment, and raise the standard of living in poor rural communities (Görgens & Van Wilgen 2004:27). Invasive alien species are removed through integrated mechanical, chemical and biological control on both state and private land to ensure that there is a water supply to dams, rivers and communities (Magadlela 2001).

Prevention, eradication and control are the three strategies for managing plant invasions (Culliney 2005:132). Invasive plants pose economic, social and medical challenges to human lives as they compete with valuable plants for sunlight and nutrients, reduce crop yields, increase crop production costs through increase in chemical and mechanical control, reduce the quality of farm products, and interfere with water management, among others (Culliney 2005:133). Mechanical controls include hand-pulling, hoeing, tillage, mowing, grubbing, chaining, bulldozing, harvesting, and draining. Biological control is an environmentally sound and effective means of reducing or mitigating pests and pest effects using natural enemies (Sanda & Sunusi 2014).

Sharma et al (2013:176) view biological control as a method to control pests thereby increasing crop yields. An example of biological control is crop rotation whereby farmers practice planting different crops on the same field. South Africa has been using biological control to reduce invasive alien species since the 20th century (Zimmermann et al 2004). The programme focuses on the creation of temporary employment, training opportunities and skills development for previously disadvantaged individuals (Magadlela 2001) who have no or limited experience (Marais, Wilgen & Stevens 2006:97). In this programme, private landowners were assisted by small enterprises of contactors to remove invasive alien plants on their land (Magadlela & Mdzeke 2004:95). More than three hundred projects in South Africa are currently operating under this programme (Magadlela & Mdzeke 2004).

Working on fire

There are investments made through the National Resource Management Programme for restoring and maintaining natural resources to achieve skills development opportunities and the creation of jobs. Working on fire is a programme to eliminate the wildfires caused by humans and to encourage the use of fire. The programme's focus is to involve communities in Integrated Fire Management and Wildfire suppression (Molina & Kraus 2010). The programmes include the importance of fire awareness, prevention, detecting fire, and the restoration from fire damage (Marais, Maitre & Frost 2015).

Forsyth, Kruger and Le Maitre (2010) acknowledge that the National Veldfire Information System is not operational in South Africa. Due to this, fires in South Africa during 2008 caused smallholder farmers to lose their livelihoods, commercial farmers lost their livestock and machinery, and the economy lost billions of rands (Forsyth et al 2010). Nkomo and Sassi (2009) suspect that smallholders may be the sources of veldfires which destroy pastures and force animals to move from one place to another.

The positive side of veldfires is acknowledged as a technique of veld management, only if is done responsibly and at the right time (DAFF 2013), as it contributes to the regeneration of plants and grasses. However, uncontrolled burning impacts negatively on soil fertility thereby increasing soil compaction and erosion (Nkomo & Sassi 2009). The South Africa Department of Agriculture Land Reform and Rural Development (DALRRD 2020) encourages farmers together with the provinces to maintain their firebreaks as indicated in Chapter 4 of the National Veld and Forest Fire Act no 101 of 1998.

Incidents of wildfires in South Africa are recorded by the DEA (2017c:44). In the Harry Gwala District Municipality, KwaZulu-Natal, fires destroyed agricultural infrastructure (grazing land, water infrastructure, homesteads, sheds and livestock) amounting to R10,2m. A local state of disaster was declared on 29 October 2014 as intense wildfires caused significant damages to 93,531 ha of natural grazing land, homesteads, sheds and livestock, farming infrastructure and water infrastructure in Mohokare (Xhariep District Municipality), Dihlabeng and Maluti a Phofung municipalities (Thabo Mofutsanyane District Municipality) in the Free State Province during August and September 2014 (DEA 2017c). A provincial state of disaster was declared by the Free State Province and emergency disaster relief amounting to R15,790,824 was used to provide animal feed in the form of fodder (DEA 2017c).

Working with woodlands

The forest and forest products industry is a major employer in the South African labour market. It is estimated that about 200 000 to 260 000 people are employed in the forest and wood processing industries but more accurate statistics are needed (Department of Water Affairs and Forestry [DWAF] 2005). About 80 000 to 100 000 are forestry workers, of whom nearly 80% are in the Mpumalanga and KwaZulu-Natal Provinces (DWAF 2005). An estimated 120 000 people are employed in industries which use wood as a primary input. About 40% of these are employed in sawmilling, 30% in pulp and paper manufacturing, and the balance in secondary processing. In addition, there are those employed by the smaller primary converters such as in making poles, matches and charcoal (DWAF 2005).

Woodland is an important forest resource due to its accessibility as it provides goods and services to many people (DWAF 2005). The FAO (2015) argues that forests play a vital role in addressing climate change by ensuring that carbon dioxide is absorbed from the atmosphere. Hence, the purpose of the National Forest Act is as follows: to manage forests and promote sustainable development; to introduce measures that will help in the protection of trees and forests; and to enhance the sustainable usage of forests for the benefits of education, environment, economic, recreation and culture (DWAF 2005:6).

Shackleton, Shackleton, Buiten and Bird (2006:554) note that one role played by forests, amongst others, is to provide employment, carbon sequestration services and to regulate water. Few woodlands are scattered in most parts of South Africa due to fires that have destroyed the environment. Some of the reasons for the depletion of woodlands involve the establishment of agricultural systems for arable farming. However, in homelands, woodlands have been destroyed for the purposes of resettlement and unsustainable agricultural development (DWAF 2005).

2.9.4.2 The Water Conservation and Water Demand Management Flagship Programme

Producing sufficient food is dependent on the availability of water for irrigation. Water is at the centre of the economy since most sectors, such as agriculture, mining, industries, and energy, require water to contribute to the country's economic growth (DWA 2013) causing the demand of water to rise. Water is a scarce resource leaving other resources, such as land, idle (Vink & Kirsten 2001). The DWA (2013:7) explains that South Africa is facing water challenges and is concerned about the security of its supply and the pollution of water.

Mutamba (2019) asserts that South Africa has imported surface water from Lesotho to support Gauteng which is the economic backbone of the country. This is confirmed by the high demand for water and high pollution rates in Gauteng (DEA 2013:13). The South African National Water Policy White Paper 1997 acknowledges that, although the Constitution of the Republic of South Africa (SA 1996) stipulates that every citizen needs to have access to clean water, the National Water Policy indicates that, due to a lack of resources, the government is unable to invest in infrastructures such as dams (DWAF 1997). Hence, the proposal from the National Water Policy White Paper is to implement water conservation programmes rather than investing in dams. Other uncommon sources of water that can impede water scarcity are desalination, water harvesting and the use of icebergs although these processes are expensive and require a large amount of energy (DWAF 1997).

Schreiner et al (2018) point out that a lot of water in South Africa is used by the agricultural sector. SANWP recognises that the viability of agriculture is determined by the availability of water (DWAF 1997). The current droughts in South Africa contribute to water insecurity. For example, Agri SA (2016) notes that, in the past, South Africa has been an exporter of agricultural produce, however, recently, the country imports staple foods from other countries due to drought.

Mutamba (2019) states that the problem of water is not physical scarcity, but also the socioeconomic factors that play a crucial role in contributing to the scarcity of water. For instance, there is a lack of political support in terms of developing policies and financing the programmes and projects to impede the challenge of water scarcity. There is also a lack of investments in water infrastructure and the unavailability or shortage of skills to manage projects that contribute to the water shortage (Mutamba 2019). Drought causes smallholder farmers to lose their livelihoods and investments in agriculture (Muthelo, Owusu-Sekyere & Ogundeji 2019). The DEA (2013) maintains that one of the techniques to maintain water security in South Africa is recharging ground water through the drilling of boreholes.

The National Water Resource Strategy 2 acknowledges that there is little understanding about availability of groundwater and the need thereof (DEA 2013:18). Projects like Working for Water may contribute to water security improvement and job creation by the Department of Environmental Affairs. The DWA (2013) mentions that the National Water Resource Strategy 2 is a response to the country’s long-term vision as articulated in the National Development Plan.

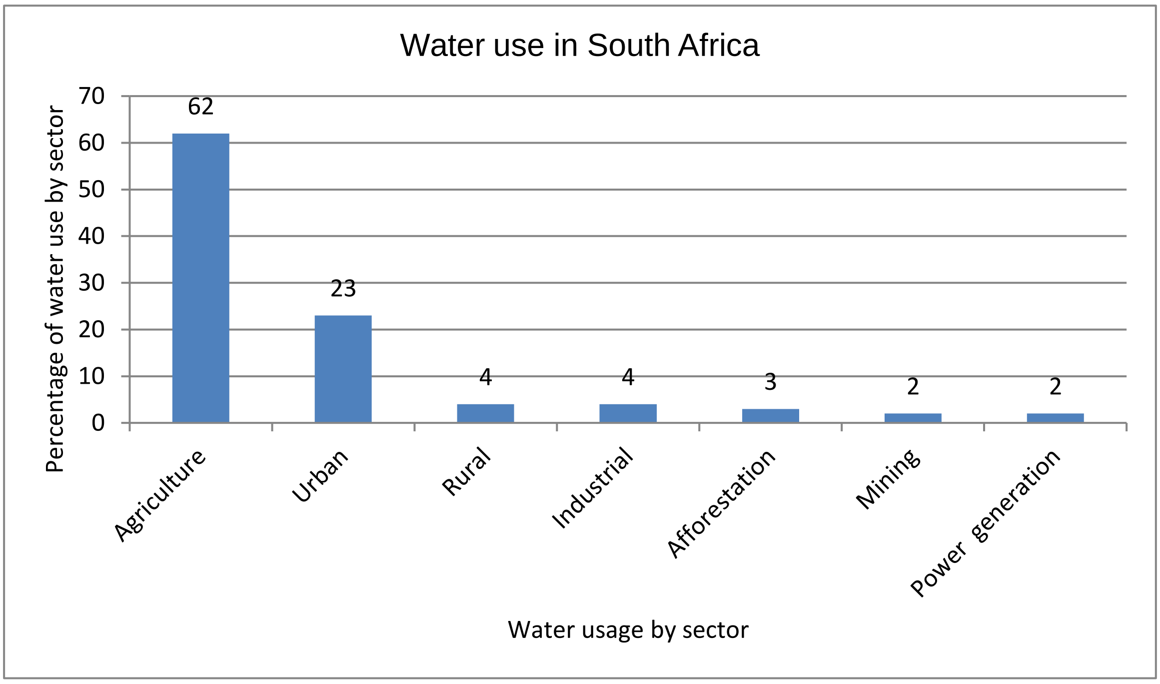


Figure 2.3: Water usage by sectors in South Africa

(Source: South African Risk and Vulnerability Atlas 2016)

The table above shows the percentage of water used by sectors in South Africa. Agriculture consumes the most water in South Africa when compared to other sectors. The rationale for water use is that many hectares of agricultural land are dominated by commercial farmers, mostly “whites” who benefited from apartheid-era policies. Furthermore, the policies granted these “whites” water rights, allowing them to irrigate a sufficient portion of their land. According to the table, agriculture uses 62% of the water, while the remaining 38% is shared among the urban, rural, industrial, afforestation, mining, and power generation sectors. Given that water is a scarce resource, smallholder farmers will suffer the most from climate change. As a result, the water issue is regarded as one of South Africa's flagship programmes.

2.9.4.3 The Renewable Energy Flagship Programme

Since the inception of the Green Revolution, mechanised agriculture has used fossil energy to improve productivity (FAO 2011) and many of the problems of fossil energy usage can be addressed by renewable energy. The SA Department of Minerals and Energy (DME 1998) facilitates the production and management of solar power, home solar systems like heating systems, solar cookers, solar pumps for water supply and others.

Many activities of the economy are either directly or indirectly linked to energy consumption making the energy sector a contributor to economic growth (Statistics South Africa [StatsSA] 2005). An increase in the price of energy and policies targeting the reduction of fossil fuel consumption have contributed to the increased production of renewable energy (Beckman & Xiarchos 2012). On-farm electricity production could eliminate electricity costs and protect the farmers from energy inflation (Beckman & Xiarchos 2012). Coal is affordable and plentiful; hence, it is a primary and dominant source of energy in South Africa. The other identified sources of energy in South Africa are biomass, natural gas, and hydro, nuclear, solar and wind power (StatsSA 2005). South Africa has the potential for solar power in the Northern Cape and wind power in the coastal regions (StatsSA 2005).

The DME (2003) posits that the Energy Policy of South Africa recognises that South Africa has undermined the development and implementation of renewable energy. However, renewable energy has been considered since the end of the apartheid era. Renewable energy occurs from natural resources that cannot be depleted. Examples of renewable energy are: solar, wind, biomass, heat, hydro, waves, ocean current, and geothermal (DME 2003). One of the energy sector's objectives, as outlined by the Energy Policy (1998), is to ensure that renewal energy services are provided to households, small businesses, small farms and communities.

South Africa contributes to climate change since its economic growth is driven by the energy sector (DEA 2011a). Musvoto, Nahman, Nortje, De Wet and Mahumani (2014) concede that smallholder farmers utilise low levels of inputs and less machinery, but this has a negative impact on the environment. Agriculture is amongst the sectors that require energy for output production. Energy can be used directly or indirectly by farmers during the transportation of agricultural products to and from market, planting, harvesting and irrigation of agricultural produce (Schnepf 2004).

Manufacturing fertilisers and pesticides are regarded as indirect energy use (Schnepf 2004) and producing fertilisers, such as nitrogen, is energy intensive. Chel and Kaushik (2011) state that solar energy can be used in various agricultural activities. For example, farmers can use solar heat for drying crops and for generating electricity from a solar photovoltaic (PV) system (FAO 2011:5). Farmers can also use residues and food processing to generate energy (FAO 2011).

The energy economy in South Africa is grouped into five energy demand sectors: agriculture, commerce and public services, industry (mining inclusive), residential and transport (DE 2012). The industrial and mining sectors consume the most energy followed by the transport sector, households, commerce and agriculture (DE 2012). Industrialisation and economic growth have led South Africa to embark on massive electrification programmes due to the high demand for electricity, particularly in rural areas. This has led the government to invest in renewable energy programmes involving wind, solar and small hydro-technology projects.

Chel and Kaushik (2011) define solar energy as energy that comes directly from the sun. The government of South Africa believes that renewable energy can be a low-cost energy service. The government's commitment is to support development through the provision of renewable energy such as solar power (DME 1998). The DME (1998) notes that the energy sector can play a crucial role in growing the economy of the country and in the creation of employment. One of the objectives of the energy sector policy is to ensure that the government promotes accessible and affordable services to disadvantaged households, small businesses, small farms and communities. The policy further proposes using clean energy to reduce the environmental impacts of energy used by industries and mining (DME 1998).

The DME (2003) empowers and encourages small farmers, cooperatives and entrepreneurs to grow energy crops that will contribute to diesel and ethanol production. This is seen as an opportunity to contribute to the South African economy through job creation (Akinbami, Oke & Bodunrin 2021). Renewable energy sources minimise coal dependency in South Africa (Akinbami et al 2021:5081) which contributes significantly to GHG emissions.

2.9.4.4 The Energy Efficiency and Energy Demand Flagship Programme

Ganda and Ngwakwe (2014:87) define energy efficiency as various technologies, strategies and by-laws that address challenges related to the utilisation of energy in commercial, industrial, agriculture and other sectors. The aim of this energy efficiency is to eliminate GHG emissions and financial costs.

The DME (2003) acknowledges that industries and consumers are not aware of energy efficiency but this can be solved through campaigns and demonstration programmes, among others. The DME (1998) estimates that greater energy efficiency could save between 10% and 20% of current consumption. For example, the DE (2016:13) is certain that energy saving measures can be an advantage to farmers through a reduction in electricity costs and high fuel prices. Therefore, the government needs to facilitate increased energy efficiency.

The Transport Flagship Programme

South Africa’s National Transport Master Plan 2050 believes that transport in the agricultural sector can expand the production and employment created by smallholder farmers through investments in agriculture and rural infrastructure (Zwane &

Montmasson-Clair 2016). In South Africa, transport is amongst the largest energy consuming sectors (DME 2003). This sector promotes climate change and air pollution as it is the emitter of GHGs (Gunawan, Bressers, Mohlakoana & Hoppe 2017). The sector therefore needs to address issues of climate change (Chakwizira 2019). Gunawan et al (2017) claim that motor vehicles contribute to GHG through emission of air pollution. South Africa has high numbers of cars, buses and other modes of transport (South African National Energy Development Institute [SANEDI] 2019). However, Chakwizira (2019) is concerned that the transport systems in the rural agricultural sector are insufficient.

The rationale behind inefficient transport systems is that roads are vulnerable to extreme events of rising temperatures, precipitation and flooding (Cullis et al 2015). This is a challenge to sectors, such as agriculture, in terms of transporting produce to market. For example, limited roads increase transport costs which means that farmers are forced to accept lower prices for their produce sold locally to cut the transport costs to market (Feng et al 2017:79). Hine and Ellis (2001) argue that impenetrable roads and high transport services contribute to wastage as crops, such as fresh vegetables and milk, deteriorate quickly.

Extreme climatic events deteriorate and decrease the lifespan of roads. Decision makers therefore need to consider future climate events when planning and designing new roads (Chakwizira 2019). Inefficient transport negatively affects agricultural marketing. Hence, the automotive sector responds to the rising demand for vehicles with lower GHG emissions to the atmosphere such as electric vehicles (DNT 2013).

2.9.4.5 The Waste Management Flagship Programme

Agricultural waste management is regarded as a complex problem due to changes in current production activities as compared to the past (Vanderholm 1984). The DEA (2011b) defines waste as: “any substance, whether or not that substance can be reduced, re-used, recycled or recovered”. Most of the agricultural waste is from inputs used by farmers, such as seeds, chemicals, and machinery (Environmental Agency 2001). Agricultural waste management deals with residues from the growing and processing of raw agricultural produce such as vegetables, fruits, crops, meat, dairy, and poultry products (Obi, Ungwuishiwu & Nwakaire 2016) which are the highest contributors to environmental pollution (Wang et al 2016:14) including non-natural waste. Sabiiti (2011) defines agricultural waste as by-products of activities of agriculture that are no longer part of primary products. Some of these residues contaminate water systems since they are deposited directly into water (Wang et al 2016:13). Examples of agricultural wastes include leaves, straw, roots, stalks, manure and others (Sabiiti 2011).

Rural areas dominate agricultural waste pollution which now exceeds the level of industrial pollution (Yang, Xiao & Gu 2021:2). The manure of free roaming animals contributes significantly to soil fertility as their manure is stored directly on the land and can be reused. The non-free roaming animals, such as dairies, poultry and pigs contribute to waste disposal (Vanderholm 1984) due to the risks of diseases and the need for vaccines to treat livestock (Environmental Agency 2001:13). Hence, Wei, Liang, Alex, Zhang and Ma (2020) advise converting agricultural waste into clean energy. Vanderholm (1984) believes that farmers should be required to practice waste management for the protection of the environment.

The DEA (2011b) is concerned about the volumes of waste generated by the rising population and economy. The State of Waste Report 2018 indicates that 55 million tonnes were generated in South Africa during 2017 (SA Department of Environment, Forestry and Fisheries [DEFF] 2020) while there is minimal landfill space. Population growth and urbanisation are the main drivers of food waste, which includes the waste of water and energy in the supply chain processes (Musvoto et al 2015:51). The waste sector has therefore become a contributor to enterprise development, job creation and energy security (DST 2010).

On farms, food waste is caused by drought, heat waves, floods, hail, wind and cold spells that reduce the quality of crops, damaging crops and lengthening the period of harvesting of crops from fields (South Africa Department of Environment Fisheries and Forestry & Council for Scientific and Industrial Research [CSIR] 2021:7). Recycling, reprocessing, and utilisation of these agricultural wastes can be beneficial to farmers since some of agricultural wastes can be returned to the land to reduce land application costs (Vanderholm 1984).

2.9.4.6 The Carbon Capture and Sequestration Flagship Programme

The International Energy Agency indicates that Carbon Capture Sequestration (CCS) is to be included as a mitigation option for the stabilisation of carbon dioxide in the atmosphere (SANEDI 2019). CCS is defined as a process which can record carbon dioxide made by humans and can store it before releasing it to the atmosphere (Folger 2013). CCS is a technology used to avert anthropogenic carbon dioxide emissions from burning of coal and gas to create electricity by entering the atmosphere (DNT 2013; Glazewski, Gilder & Swanepoel 2012:9; SANEDI 2019).

The plan to capture and store carbon dioxide in South Africa was approved by Cabinet in 2012 (Glazweski et al 2012). Strategies, such as compost application, crop rotation and diversity, integrated crop and animal production, use of intermediate and catch crops and cover crops, and zero or reduced tillage, have the potential to increase soil carbon sequestration and lower GHG emissions (FAO 2008).

2.10 Climate change adaptation strategies

Farmers' main reasons for adaptation include the unfavourable effects of climate change, such as water shortages brought on by drought. Farmers use adaptation measures to mitigate climate change-related vulnerabilities that cause poverty, particularly in African countries. Adaptation tactics are employed either before or after farmers are impacted by climate change. Farmers can reduce their exposure to risks by utilising adaptive strategies to prevent low crop yields. The UNFCCC (2007:35) revealed how farmers in the following countries on different continents adapted to the impacts of climate change.

In Latin America, local adaptation coping strategies include a variety of agricultural practices, ecosystem protections and methods to adapt to extreme events. Farmers in Peru use “waru waru” which is an irrigation and drainage system (Torres & Friàs 2012). The shallow canals of this system provide moisture during droughts and drainage during the rainy season. The “waru waru” lower the risk of damage done to crops by frost during the night and by droughts giving the farmers bigger harvests.

In Africa, rural farmers execute a range of agricultural techniques as coping strategies and tactics to enable sustainable food production and deal with extreme events. According to the UNFCCC (2007:35), adaptation strategies executed by rural African farmers include: intercropping and crop diversification; planting in home gardens; and the diversification of animals and incomes. The study in Nile Delta Region in Egypt by Kassem, Bello, Alotaibi, Aldosri and Straquadine (2019:11) concurs with the UNFCCC (2007:35) that some of the farmers have adopted changed cropping patterns, mixed cropping, crop rotation, tree planting, changed planting dates, cultivation of drought-resistant varieties, cultivation of salinity-resistant varieties, applying modern irrigation systems, adjusting irrigation scheduling, night irrigation (in summer), making and using compost, rationalising mineral fertiliser usage, mulching, and maximising the use of manure and conservation tillage.

Mapanda, Chitja and Duffy (2016:332) give examples of strategies used in African countries, for example, the Bara Province in Western Sudan has introduced sheep in place of goats; Senegal, Burkina Faso, Madagascar and Zimbabwe use pruning and fertilising to double tree densities and prevent soil erosion in semi-arid areas; southern Africa manipulates land use leading to land use conversion, e.g. a shift from livestock farming to game farming; Burkina Faso has introduced water conservation techniques to cope with arid conditions such as the Zaï technique in which farmers dig pits in the soil to collect organic material carried by the wind during the dry season. At the start of the rainy season, farmers add organic matter from animals which attracts termite activity resulting in deep termite tunnels that collect rain and increase soil fertility.

In Asia, farmers in Bangladesh and the Philippines have traditionally observed a few practices to adapt to climate variability, for example, intercropping, mixed cropping, agro-forestry, animal husbandry, and developing new seed varieties to cope with local climate (Zhu et al 2011). Various water uses and conservation strategies include: terracing; surface water and groundwater irrigation; and diversification in agriculture to deal with drought.

2.10.1 South African smallholder farmers' climate change adaption strategies

From the climate change projections and impacts observed, it is clear that smallholder farmers experience climate change in South Africa. They must therefore adapt to climate change to improve their agricultural production. Adaptation options differ from region to region, farmer to farmer depending on the adaptive capacity of that particular region or farmer. In some countries in Africa, including South Africa, significant number of farmers have adapted by the increased use of irrigation (Akinnagbe & Orohibe 2014:411). This is because some crops require sufficient water especially during high temperatures.

Benhin (2006:45) found that adaptation strategies adopted by farmers in South Africa include: changes in planting dates; increased chemical applications; increased utilisation of irrigation, shade and shelter; conservation practices; and crop insurance. According Ncube et al (2016:11), some adaptation strategies perceived important in the study conducted in Lambani village, Limpopo Province, were: planting drought resistant crops; the use of high yield varieties; irrigation systems; the use of organic fertilisers; and conventional and zero/minimal tillage farming systems. Ubisi, Mafongoya, Kolanis and Jiri (2017:34) revealed some of the adaptation strategies in Limpopo as eating less food as female farmers changed their diets. It is evident that not all farmers will be successful in implementing these techniques since some strategies require access and availability of resources together with government support.

A study conducted in South Africa by Van Rensburg et al (2007) found that indigenous vegetables, such as cucurbita maxima and C. pepo, can withstand drought conditions as they need only a small amount of water. Fertilisers, especially farm manure, have a favourable effect on cucurbits. Cowpeas are a drought- and heat-tolerant crop with lesser requirements for soil fertility than many other crops (Van Rensburg et al 2007).

In KwaZulu-Natal, smallholder farmers' adaptation to the consequences of climate change primarily consist of three strategies that are a direct reaction to the problem of the water deficit: altering planting dates; growing drought-tolerant or short-season crops; and implementing soil conservation measures.

A study conducted in the Eastern Cape by Mdoda (2020) found that strategies differ depending on the type and nature of the farmer's problem and are related to climate variability. Approximately 80% of farmers in Mdoda’s (2020) study used crop adaptation strategies to reduce the impact of climate variability on crop productivity. The most common strategies for mitigating the impact of climate variability, in order of importance, were: changing planting dates; crop rotation; using irrigation; planting different crop varieties; mixed cropping; changing crop variety; and crop diversification (Mdoda 2020).

The most common adaptation techniques employed by smallholder farmers in the study area included: water harvesting; crop diversification; soil conservation; soil fertility improvement, whereas increasing the amount of land used for crop production, changing the crop type, and switching from crop to livestock production were among the least common (Myeni & Moeletsi 2020). Although literature showed that farmers in South Africa are adapting to climate change impacts, there are barriers hindering these farmers from adapting to climate change.

2.10.2 Barriers to adopting climate change adaptation strategies

With many risks to farmers as a result of climate change, the repercussions may worsen the challenges that they face when dealing with the effects of climate change. Therefore, in order to successfully respond to climate change, the agriculture sector has to identify and overcome potential barriers to implementing climate change adaptation strategies. The World Bank Group (2017) found that most of smallholder farmers do not have access to productive resources, the agricultural banking sector, new technology, or markets that may help them increase production and revenue. In this case study, the technologies used by smallholder farmers were unknown.

Biesbroek, Klostermann, Termeer and Kabat (2013) believe that there is no consensus regarding the definition of barriers to adaptation. Biesbroek et al (2013) further state that the concept of “barriers” is often used interchangeably with synonyms and other concepts, including “hindrance” and “constraint”. However, Moser and Ekstrom (2010:22026) define barriers as hurdles that require a combination of stakeholders to be achieved.

According to the Productivity Commission (2012:74), a barrier is “anything that prevents the community from using its resources – natural, financial, human, social and physical capital – in the most advantageous way to respond to climate change”. As indicated by Biesbroek et al (2013), understanding the nature of barriers to adaptation is important to find strategic ways of dealing with them.

Wreford, Ignaciuk and Gruere (2017) distinguish between barriers at farm level and barriers at sector and policy levels. Barriers identified at farm level include social, cultural and behavioural factors. These barriers prevent farmers from adapting to climate change.

2.10.2.1 Political barriers to adaptation

Policies are identified as barriers of adaptation at sectoral level. For example, the study conducted by Bryan et al (2009) and Gbetibouo (2009) found the most important barriers revealed by Ethiopian and South African farmers were a shortage of land and lack of access to credit respectively. Tibesigwa, Visser and Turpie (2015) identify a lack of information, a lack of government support, a lack of education and skill as barriers to adaptation by farmers in South Africa.

Adger et al (2007) identify a lack of funding from government, a lack of institutions that facilitate financing adaptation, limited access to financial resources, a lack of resources to monitor progress, or a lack of political willingness to mobilise financial resources as barriers to adaptation.

Other barriers identified by Bryan et al (2009) and Tibesigwa et al (2015) are a lack of: access to water for irrigation, information about climate change, market access, wealth, government farm support and access to fertile land. Barriers are also inappropriate adaptation responses, and insecure property rights, information on climate and insufficient access to inputs. Aliber and Hall (2012) and Maponya and Mpandeli (2013) found that a lack of extension support within the provinces of South Africa was a barrier to smallholder farmers adaptation.

Under political barrier, the dominance of political authority was identified by Jones and Boyd (2011) as a key barrier to adaptation. This barrier occurs where there is negligence by political, community, government, NGOs or leaderships. For example, farmers who do not have long-term security on their land are unlikely to make adaptations that involve investments and physical infrastructure (Jones & Boyd 2011; Wreford et al 2017:13). On the other hand, the changes in agricultural practices associated with infrastructure could prevent farmers in a particular region, especially in developing countries, from adapting to climate change because farmers in those countries have limited resources (Wreford et al 2017).

2.10.2.2 Technological barriers to adaptation

Technological change has been the main driver to increase agricultural production and profits (OECD 2001). The challenges encountered by farmers included: a lack of capital; a lack of knowledge on the utilisation of technology; and market risks. Farmers need to be able to compete internationally by producing products of high-quality utilising emerging technologies which are aligned and acceptable by regulations and environmental standards (OECD 2001). Zhu et al (2011:14) believe that technology contributes significantly to the livelihoods of people. Farmers must familiarise themselves with technology to improve their production and to thrive in the agriculture business (OECD 2001).

The UNFCCC (2015) defines technologies for adaptation as “the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change”. Applying technologies for adaptation is a complex process that requires the integration of multiple issues, stakeholders and scales. The appropriate application of technologies demands consideration of the political, economic, social and ecological context.

Zhu et al (2011) identify hard and soft technologies as applicable to farmers. According to the UNFCCC (2007:32) and FAO (2013:6), hard technologies include machinery, equipment such as new irrigation systems or drought resistant seeds and tools which are utilised to produce goods and services. According to Zwane and Montmasson-

Clair (2016:8), some climate change adaptation policies in South Africa do not consider the issue of breeding of drought tolerant livestock and crop varieties. Examples of soft technologies that farmers can use to adapt to climate change are: crop rotation; agroforestry; mixed cropping; and the conservation of water (Barnard, Manyire, Tambi & Bangali 2015). In addition, soft technology includes insurance schemes, crop rotation patterns and the skill or experience a farmer has to operate a sprinkler irrigation. Early warning systems, crop varieties and irrigation systems are other technologies identified by Antwi-Agyei, Dougill & Stringer (2013:8).

2.11 South African climate change stakeholders and their roles

Climate change adaptation can be achieved through involvement and mobilisation of resources from a wide range of stakeholders. Stakeholders are defined as individuals who represent a particular group of people who are interested in finding solutions to the same problem (Sagar 2017:41). These influential individuals or groups can also be influenced by others to achieve the same goal (Fassin 2008:09). The involvement of stakeholders can create opportunities to improve the application and successful monitoring of policies. Examples of stakeholders involved in climate change are: scientists; advisors; farmers; businesses; researchers; households; governments; NGOs; and extension officers, among others.

Ziervogel, Cartwright, Tas and Adejuwon (2008:3) identify climate change stakeholders as: climate science experts; agricultural practitioners and technicians; local communities/civil society; donors; and policy makers. For example, at national level, the government develops adaptation policies and strategies and the provincial level ensures that provincial strategies and policies are aligned to the national strategies and policies. According to Black, Bruce and Egener (2010:5), the local government incorporates the national plans into the IDP for implementation at local level.

Local governments are accustomed to dealing with climate-related issues during their planning and management activities. For example, they manage water supplies, design drainage systems and flood protection, design and implement heat and smog alert systems, and control mosquitoes and other disease vectors. However, Black et al (2010) believe that most municipal strategic or long-range plans do not address adaptation to climate change, and it can be difficult to get the issue onto the municipal agenda. Government also has a vital role to play in ensuring that businesses are supported, encouraged and motivated to adhere to the development of adaptation and implementation of adaptation strategies in their businesses as stipulated in climate change laws. Government intervention, in the form of regulations or the funding of public goods and services, has the potential to facilitate more effective adaptation to climate change and hence better community outcomes (Productivity Commission 2012:3).

Despite the crucial role that government plays, there are certain areas where government is not able to invest in due to a lack of information. Therefore, civil societies can assist in closing the gap between the state and people (European Union Agency for Fundamental Rights 2017:13) through provision of information. It is the responsibility of civil societies to evaluate, comment and respond to the initiatives of government and private sectors since they raise public awareness and motivate individuals, institutions and authorities to adapt to the effects of climate change and they also communicate climate information.

The other important source of information to farmers is through extension officers. Extension officers assist farmers to put into action the policies of government. Tripathi (2016) discovered that agricultural extensions are in a better position to encourage farmers to adapt to climate change. According to Nhemachena, Hassan and Chakwizira (2014:236), farmers with access to extension services adapt to climatic conditions rather than quitting farming. Scientists and researchers work together to ameliorate projections of climate change and its impacts within communities and sectors which are affected. Climate change could only be successful if all stakeholders are involved through participation. This will offer stakeholders an opportunity to share climate change information, resources and strengthen their collaborations.

The DEA (2017b:21) emphasises that climate change adaptation is not a matter for environmental professionals or climate change officials, but that all South Africans should work together to create a secure and prosperous future. The early warning information system in South Africa is produced by the South African Weather Service (SAWS) as it is mandated by the Weather Service Act 2001 to produce weather and climate information as well as to provide early warning alerts. According to the Department of Environmental Affairs, SAWS works closely together with government departments, private institutions, communities and research organisations, National Disaster Management Centres, provincial government departments, municipalities and communities.

Although social media is the fastest instrument to help famers in accessing climate information, local municipalities, civil societies as well as non-government organisations and other key stakeholders operating at local levels can facilitate the collection of socioeconomic climate information. Other climate change stakeholders' roles and responsibilities have been extensively outlined in the National Adaptation Strategy of South Africa which is used to implement National Climate Change Response White paper 2011. It means decision makers and policy developers should include both human and financial resources during planning to make sure that adaptation is effectively carried out.

2.12 Chapter summary

The chapter's focus has been to better understand the concept of climate change. Climate change-related themes, such as projections, causes, risks and adverse impacts, farmers' challenges in adapting to climate change, as well as methods developed and adopted at the international, national, and agricultural levels to lessen its adverse effects, have been discussed. The adopted PMT as a theoretical framework, and its components have been shared. The following chapter discusses the socioeconomic aspects of the study area and the methodology employed in this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The chapter discusses how the research is carried out. The chapter begins with a description and discussion of socioeconomic features in the study area. Following that are the justifications for using the pragmatic paradigm, which influence the study's approach. The chapter also discusses the mixed research approach, design, and procedures used in this study. These techniques include population and sampling, as well as methods for data gathering, analysis and processes. The study covers tools, including focus groups, key informants, surveys, observations, and survey questionnaires. Before the chapter concludes, the ethical implications of this research and methodological challenges are discussed.

3.2 Description of the study area

GRASP Secondary Cooperative in Ba-Phalaborwa local municipality in Limpopo Province of South Africa was used as a case study for this research. Ba-Phalaborwa Municipality is found in Limpopo Province's Mopani District, where poverty as well as unemployment are prevalent (Ba-Phalaborwa Municipality 2022). Ba-Phalaborwa is one of the Mopani District's five local municipalities. The Kruger National Park is included in the municipality's geographical territory of 7461.6 km^2. With the addition of the Kruger National Park in the 2011 delineation, the municipality's land size has more than quadrupled from 3001 km^2. The Municipality is a handy entry to the Kruger National Park and the Transfrontier Park, which extend all the way to the Mozambique Coast (Ba-Phalaborwa Municipality 2022).

Ba-Phalaborwa Municipality is mostly a rural medium-sized municipality. It is made up of 35 settlements and four towns (Gravelotte, Namakgale, Lulekani, and Phalaborwa). The location was selected because farmers in Limpopo need effective production adaptation strategies to reduce vulnerability to the consequences of climate change and variability (Afful & Ayisi 2018). The other reason for selecting these villages was that Limpopo has the second-highest percentage of agricultural households in South

Africa according to StatsSA (2018) with majority depending on agriculture for a living.

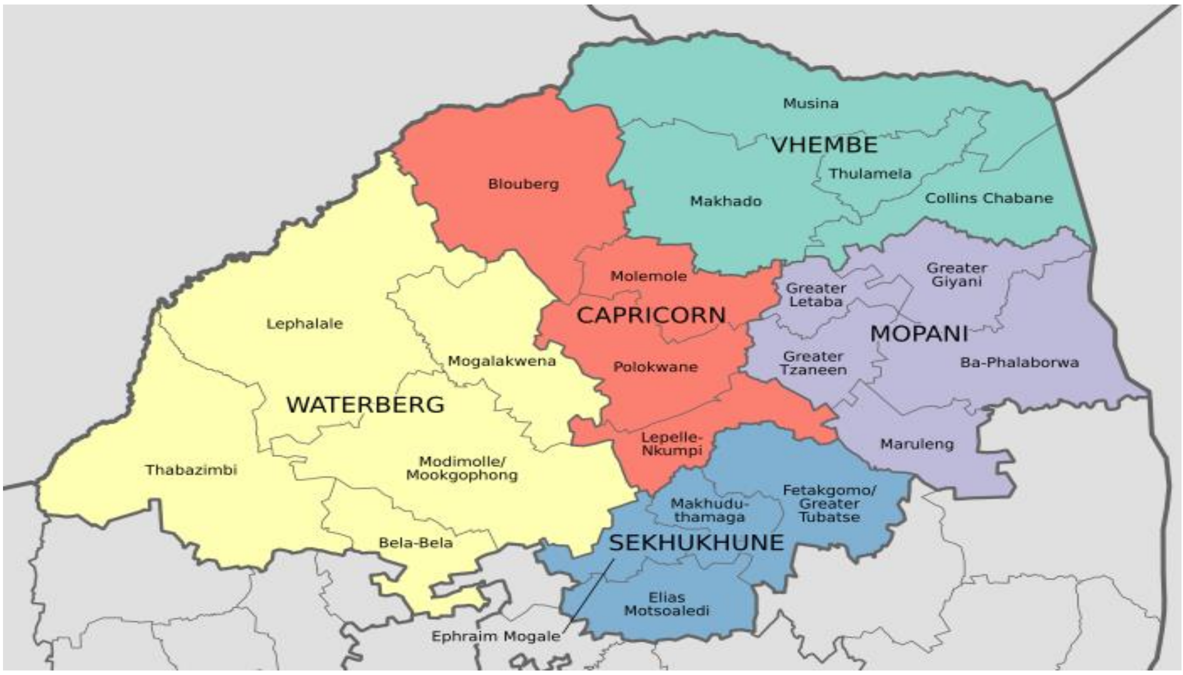


Figure 3.1: Map showing five district municipalities and 25 local district municipalities in Limpopo

Figure 3.2: Map showing South Africa's nine Provinces

3.2.1 Socioeconomic characteristics

Socioeconomic profiles provide evidence for actions on policies for social and economic concerns. These statistics are analysed to reflect the population's current and future demands in terms of the types and extent of social needs such as health, education, and employment (Denema 2005). Limpopo Province has the fifth largest population in South Africa with an estimation of 5.9 million people who are almost ten percent (10%) of the total national population (StatsSA 2018). Ba-Phalaborwa local municipality in Limpopo Province contributes 168 937 (StatsSA 2016) to the provincial population with 49 100 households. The villages of Gravelotte, Selwane, and Priska in Ba-Phalaborwa, where the case study project was based, have populations of 1098, 5263, and 626 respectively (Ba-Phalaborwa Municipality 2022).

From the population of 168 937, 94.3% are Black Africans and the remaining percentage is spread between Coloureds, Indians/Asians and Whites with 63% of the population being youth (Ba-Phalaborwa Municipality 2022). In South Africa, one of the essential socioeconomic factors for development is education, which is also one of the fundamental human rights. Higher education, in particular, gives a good indicator of the degree of human development and the talents that are accessible in a certain field. Additionally, it describes the market capabilities that the labour force possesses and how that affects employment growth in a particular region (Ba-Phalaborwa Municipality 2019). In terms of education, 33.7% of the Ba-Phalaborwa population aged 5-24 attended an educational institution in 2016 (StatsSA 2016). The high percentage of persons attending education institutions is due to population growth between 2011 and 2016 (Stats SA 2016).

The municipality’s unemployment rate surpasses education, at 37%, with 50.20% unemployed youths (Ba-Phalaborwa Municipality 2019). StatsSA (2016) identified inadequate employment as one of the challenges perceived by municipalities in Limpopo. According to the municipality's economic data, around 87.3% of the local population earns less than R6 400 per month, with 43% earning nothing at all (Ba-Phalaborwa Municipality 2019). From 87% of the population earning less than R6 400 per month, 60 969 people receive grants as a source of income (Ba-Phalaborwa Municipality 2022). The information helped the researcher to assess the adaptive capacity of smallholder farmers in the area.

3.3 Research philosophy

The researcher followed a pragmatic paradigm in this study. The rationale behind that was that a pragmatic paradigm gives the researcher an opportunity to address the weaknesses emanating from both a positivist paradigm and an interpretivist paradigm. The researcher who chooses a pragmatic paradigm is not aligned to any philosophical assumptions (Wilson 2014). Cameron (2011:101) defines pragmatism as a practical approach to a problem that has strong associations with mixed method research. Teddlie and Tashakkori (2009:73) agree by stating that pragmatists have a mutual relationship with mixed methods.

The philosophical stance of pragmatists is that knowledge and understanding should be extracted from direct experience (Easterby-Smith, Thorpe & Jackson 2015:877). Pragmatists prioritise research problems and research questions when conducting their research and they choose methods they regard as pertinent to provide information for their research (Wilson 2014). The other reason for choosing this paradigm is to identify weaknesses in the study and to use a mixed method approach to strengthen it (Rahi 2017). The researcher's belief is that a research problem can be addressed by using multiple paradigms as suggested by Creswell (2006:15) and to contribute to practical solutions that inform future practices (Saunders et al 2015). Thus, for the mixed methods researcher, pragmatism opens the door to multiple methods, different worldviews, and different assumptions, as well as to different forms of data collection and analysis in the mixed methods study (Creswell 2003:12).

Pragmatists believe that inquiry is value free and that value (axiology) plays a crucial role during research and drawing conclusions from their studies (Subedi 2016). Having identified and discussed the paradigm followed in this study, the researcher discusses the approach which was appropriate for this study.

3.4 Research approach and design

A research approach is a research plan and processes that vary from broad assumptions to specific data collection, analysis, and interpretation methods (Creswell 2014). This study followed a mixed methods approach. According to Addae and Quan-Baffour (2015:151), philosophical assumptions drive the approach to understand social phenomena. The complexity of the study problem also influenced the choice of mixed methods approach (Creswell 2014) and complex research problem cannot be addressed from the unique perspective of a quantitative or qualitative study (Ponce and Pagán-Maldonado 2015). The study is about climate change, which is a complex problem, and the researcher’s belief was that a single approach was inappropriate for this study. Choosing a mixed technique approach produced additional information when compared to information from either qualitative or quantitative (Creswell & Creswell 2018:4).

Hence, my knowledge claim of the mixed method approach has been founded on pragmatic grounds (Creswell 2014) to understand climate change problem, causes, impacts, challenges, consequences, and strategies to tackle the problem.Using both approaches helped the researcher to gain an in-depth understanding of climate change from the perspectives of participants in a qualitative sample and to generalise the perspectives of participants in a quantitative sample (Bazley 2002). This approach broadened and confirmed a study's results (Schoonenboom & Johnson, 2017:110) and produced research results that are stronger than one individual method (Malina, Nrreklit & Selto 2011:61) while also suppressed the bias of the other method (Creswell 2003). Furthermore, the approach improved accuracy and completeness, and contributed to the overall validity of this study (Ponce & Pagàn-Madonado 2015; McKim (2017).

The design for this study was an exploratory sequential mixed method design. This mixed method design allowed the researcher to mix both qualitative and quantitative data. A research design is defined by Webb and Auriacombe (2006:589) as a path which is developed and followed by a researcher to achieve their goals. The exploratory sequential mixed method design assisted the researcher to utilise both quantitative and qualitative methodologies in this study and to expand on the findings of one method using another (Creswell 2009; Kroll & Morris 2009). As advised by Greene, Caracelli and Graham (1989:267), the design allowed the implementation of one method first (qualitative); the findings of the first method helped to identify the sample, then the instrument which informed the analysis of quantitative method was developed.

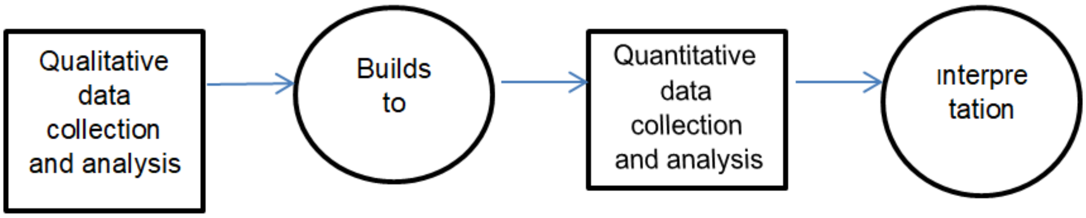


Figure 3.3: Sequential exploratory mixed design

3.5 Description of the research design

The first phase of the qualitative method used a case study followed by survey design in the second phase. Crowe, Creswell, Robertson, Huby, Avery and Sheikh (2011:1) define a case study as a design utilised to gather extensively the mixed concerns of a complex issue. Neale, Thapa and Boyce (2006:3) believe that case studies give a description of what happened, when, to whom and what were the consequences thereof. This case study explored the occurrences of events in order to describe, explain and provide rich data obtained from the participants (Daymon & Holloway 2005). Other strengths of a case study are that it focuses on words and the instrument is the researcher who is involved with participants under study.

A case study design helped the researcher to select a case that gave as much information as possible to comprehend the case holistically (Kumar 2011). Case studies are the preferred research strategy when the phenomenon cannot be isolated from its context, the focus is on contemporary events, and the experiences of the actors are important (Iacono, Brown & Holtham 2009:40). The case study design allowed the researcher to employ a variety of techniques to acquire data, including in-depth interviews, information from secondary records, data from observations, and data from focus groups and key informants. This process of employing multiple data sources within the same study is referred to as “triangulation” (Wilson 2014; Sarantakos 2013).

Holloway (2005:7) observe that some of the weaknesses of qualitative research are: being too subjective, difficult to replicate, and generalisation challenges. These weaknesses were addressed by second phase (quantitative phase) which used an instrument to collect quantitative data.

The second design of this study, which was quantitative, followed a survey strategy. The themes developed from the case study assisted the researcher to develop a survey instrument used to collect quantitative data which was the second phase of the study (see table 3.3). These themes were: extreme climatic events; high socioeconomic loss; limited adaptation strategies; a lack of resources; and agricultural investment. These themes are discussed in Chapter 4. The purpose of the survey design was to collect data consistently from a considerable number of respondents (Briggs et al 2012:140; Wilson 2014). Creswell and Creswell (2018:147) point out that a quantitative description of trends, attitudes and opinions of a population or tests for variables of a population is gained through a survey design. The survey provided information about certain aspects of the population (Bethlehem 2009).

For the purpose of this study, smallholder farmers who did not form part of the focus group were identified as a sample to quantify the findings in the area of the study. This quantitative design assisted in answering some of the descriptive questions, questions about relationships between the variables (Creswell and Creswell 2018:147).

3.6 Study population and sampling

The population of this study was smallholder farmers in Limpopo Province of South Africa. According to Aliber and Hart (2009), one million Blacks in Limpopo Province practice agriculture. The province was selected because it encounters significant reductions of agricultural resources due to continuous droughts and floods (LDARD 2019). The sampling frame or target population is a defined as a group of people with the same characteristics that can be recognised by the researcher for conducting a study (Creswell 2012:142). For the purpose of this study, the sample was selected from Ba-Phalaborwa Local Municipality in the Mopani District of Limpopo Province in South Africa – Gravelotte, Selwana and Priska.

As this study had a mixed method approach, both qualitative and quantitative samples were drawn from the same population. The researcher used an up-to-date list of members of GRASP with their contact details, gender, age, number of hectares, location, local municipality, district, province.

Two focus groups, one of six (6) females and the second of six (6) males and 12 key informants (extension officers, an animal expert, agricultural economist and AAPs), represented the qualitative phase and 50 respondents represented the quantitative phase with 19 females and 31 males from the list of 78 smallholder farmers of GRASP. Mishra (2016) is concerned that mixing genders can have a serious impact on data. These groups were separated to ensure that all participants contributed meaningfully to this study.

These key informants were included because the researcher believed that, as they work with smallholder farmers vulnerable to climate change, their contribution in terms of information provision ensured the validity of the findings.

3.6.1 Sampling techniques and procedure

The accuracy of the findings is determined by the way researchers select their samples (Kumar 2011). The researcher adopted idea by Dawson (2002) and identified simple random probability and purposive non-probability sampling as two types of sampling techniques appropriate for the study. This is because of the pragmatic paradigm and mixed approach followed by the researcher. The sample for the qualitative phase of this study were two focus groups of males and females with six members in each group, and 12 key informants who are officials from the Limpopo Department of Agriculture. The quantitative sample comprised 50 respondents with 19 females and 31 males. This was because of the lottery method used to choose respondents. The method is explained later in this chapter.

The reason for selecting two sampling methods was to cover the bias, identified by

Kumar (2011), which can occur when a researcher chooses a non-probability sampling method. Kumar (2011) mentions that the selection is influenced by the researcher. The processes followed when selecting sample are discussed in the next section in this chapter. The other bias of non-probability, according to Kumar (2011), is when the sampling frame fails to cover the whole situation. To avoid this (Kumar 2011), the researcher requested an updated list of all members of GRASP.

3.6.1.1 Sampling procedure of smallholder farmers, key informants

For the purpose of this study, the participants for the non-probability sample were chosen based on criteria developed by the researcher which were their homogeneous characteristics (Omona 2013). Firstly, the criteria explained what was required from participants to participate in this study (Hornberger & Rangu 2020). Secondly, developing inclusion criteria or specifying characteristics was to ensure that the study can be reproducible (Hornberger & Rangu 2020). Thirdly, the criteria was to eliminate participants who did not qualify to be participants of this study.

The advantage of homogeneity was that participants were comfortable sharing their experiences and opinions (Hennink 2014; Flick 2018) because most of the group members knew each other (McLafferty 2004). The other reason was that the participants had all experienced climate change. All the participants within both focus groups were screened and met the inclusion requirements. Because the researcher was unfamiliar with climate change officials in the region where the study was performed, purposive-network sampling was employed to select key informants.

Key informants, particularly extension officers, were included because they are the most valuable source of information to assist farmers to adapt to climate change (Maponya & Mpandeli 2013). Officers are exposed to various information forums and programmes that could assist farmers to adapt to climate change. The table below summarises the inclusion criteria of this study.

The selection of quantitative respondents of simple random sampling was done through the lottery method (Acharya et al 2013). The lottery method allowed the researcher to give every member from the target population a number and the number was written on a small paper (Mohsin 2016). Participants who participated in the focus group interviews were excluded. The small paper was folded and put into a small container. The researcher mixed them and then fifty (50) small papers were picked from the container. This was sampling with replacement because, if the participant was selected but was not available to participate in the study, another person was then selected (Kumar 2011).

Both smallholder farmers and key informants provided information (Lopez & Whitehead 2013) that helped the researcher to achieve research objectives, questions, purpose and goal of this study as discussed in Chapter 1. Table 3.1 below indicates the criteria used to select participants.

Combining the two approaches enabled the researcher to create complementary databases that included information that was both deep and broad about the topic under investigation (Teddlie & Yu 2007).

Table 3.1: Inclusion criteria of participants in this study

Inclusion criteria	**Defining criteria**
Area of residence	Participants must stay in three villages near GRASP Project next to the main road. The distance between the three villages is ±40km
Age	Participants must be between 30 and 70 years old
Gender	Participants must be either female or male
Climate change knowledge	Participants must have a minimum of 10 years' experience in farming
Consent forms	Participants must sign consent forms
Member of GRASP	Participants must be members of GRASP
Population	Participants must be smallholder farmers in Limpopo Province
Language	Participants must speak English

3.6.1.2 Gaining access to research site

Creswell and Clark (2018) identify one of the recruitment strategies as gaining access to sites and participants through permission. Patton and Cochran (2002:17) suggest three ways of recruiting participants. Firstly, a researcher can ask participants from the population to volunteer; secondly, a researcher can ask gatekeepers to assist in inviting participants on behalf of him or her; and lastly, the researcher can use sample frame to invite participants.

In conjunction with ways of recruitment as highlighted by Patton & Cochran (2002), the researcher managed to recruit participants for this study. The processes of attaining physical access to conduct the study were submitted and approved by the Ethics Research Committee in UNISA during May 2021. Access to gatekeepers was through the Approved Ethical Certificate which gave the researcher permission to conduct research as per UNISA rules and regulations pertaining to ethics (see Annexure B). Gatekeepers granted permission to the researcher to conduct the study (Saunders et al 2009:170). Saunders et al (2009:178) believe that requests are more successful when a researcher sends a letter to a gatekeeper therefore the researcher submitted letters requesting approval from the gatekeepers. The researcher waited for the ethical committee from UNISA to grant approval to conduct the study.

The reason for obtaining approval from an ethical committee (UNISA) is because the committee protects the rights of participants and assesses the level of risk and the possible harm caused by conducting research with the participants before granting permission to conduct the study (Creswell & Clark 2018). Upon receipt of approval from UNISA, the researcher submitted a copy of the ethical certificate to the gatekeepers. The gatekeepers granted the researcher permission to conduct the study in writing. Firstly, the researcher organised a meeting to meet the gatekeepers (committee members) of the project and explained the purpose of the study and the benefits thereof. The way forward was for the gatekeepers to organise a meeting between potential participants and the researchers. Due to COVID-19, the meeting did not take place.

The gatekeepers further gave the researcher a list of all smallholder farmers of

GRASP. The list included, amongst others, village names where smallholder farmers live, IDs, contact numbers, genders, segregation of whether a member is adult, youth or disabled, land size, etcetera. This kind of information helped the researcher to identify and select the people whom she thought were appropriate for participating in the study using the specified criteria in Table -3.1. Selecting participants was done telephonically due to the COVID-19 outbreak. The researcher created two WhatsApp groups for smallholder farmers who showed interest. One group was for the six females and the second group was created for the six males. Gaining access to key informants was through a permission granted by LDARD. See attached permission letter as Annexure C.

These participants were further given consent forms which outlined the purpose of the study and the nature of the study so that they were able to make informed decisions whether to participate or not (Johnson 2014). The final inclusion considered participants who signed informed consent forms. This was part of protecting information from research participants. Lastly permission was granted by participants themselves (see Annexure D).

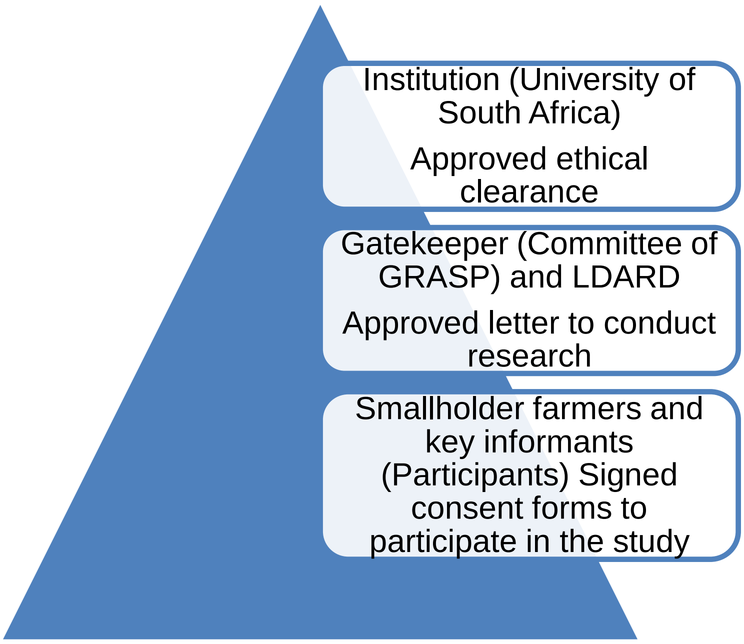


Figure 3.4: Hierarchy of accessing participants of the study

3.7 Data collection tools

The entire study's interviewing process took place between April 2022 and July 2023. The Department of Agriculture offices in Lulekani, Gravelotte, and Selwane villages hosted the interviews. Easterby-Smith, Thorpe and Jackson (2015) advise that the choice of a data collection method should be derived from the study's objectives therefore both interviews were based on the objectives of this study as outlined in Chapter 1.

As a mixed method, the study followed both qualitative and quantitative data collection in sequences. In Phase 1, qualitative data collection was in focus group interviews, participant observations, field visits, note taking and audio recording. Phase 2, quantitative data collection followed questionnaires. The qualitative data collection methods gave the researchers insights about the concept of climate change from the views of participants and the measures taken by participants to protect themselves from its impacts. These methods also helped the researcher to identify key themes through the coding of qualitative responses (Green, Duan, Gibbons, Hoagwood, Palinkas & Wisdom 2016:5).

The themes helped to develop a quantitative data collection instrument. Quantitative data helped the researcher to categorise and code the socioeconomic profiles of smallholder farmers for the purpose of analysis. These instruments are briefly defined and discussed to give an overview on how data in this study were collected.

3.7.1 Focus group

Focus groups are an effective exploratory tool in qualitative research. According to Freitas, Oliveira, Jenkins and Popjoy (1998), a focus group is a type of in-depth interview accomplished in a group, whose meetings present characteristics defined with respect to the proposal, size, composition, and interview procedures. According to Mishra (2016), a focus group is a process whereby people with same background and experience are gathered together for the purpose of discussing a particular topic.

Focus groups were chosen because they supplied sufficient information based on the experiences and opinions of participants (Mishra 2016), and participants also gave meaning to their viewpoints. Another advantage was that focus groups were useful in nonverbal communication (Then, Rankin & Ali 2014:16). A matrix table including nonverbal communication is attached as Annexure I. This type of information cannot be gathered using other instruments, which detach the researcher from the setting.

3.7.2 Participant observation

The second qualitative data collection method was participant observation. The rationale for participation observation was that the researcher believed that the strategies practiced by smallholder farmers to deal with climatic events were visible for insiders and to people who were permitted to be around them, hence, the participant observation. Observations helped the researcher to observe events as they naturally occur (Flick 2006:219). Based on that, the researcher assumed that overt observation was appropriate for this study since Saunders et al (2015) regard covert observation as unethical.

Overt participation allowed the researcher to reveal the purpose of conducting research to the participants while under covert observation, the purpose of research could not be revealed to participants (Li 2008:101). Revealing the study purpose made it easier for the researchers to take notes, audio recordings, pictures and to ask probing questions during focus group discussions (Creswell 2012) with smallholder farmers and key informants. The consent form (see Annexure D) is a proof of voluntary participation in this study. Pandey and Pandey (2015:64) view observational data as more true and realistic than other data collection methods.

With observations, the researcher studied and documented what individuals do – their everyday behaviour – and try to understand why they do it (Paradis et al 2016). The other purpose of observation in this study was to ensure that silent members within the focus group, due to shyness, a lack of time for them to speak, those who agree by yes or no, and members agreeing nonverbally (for example by nodding head, smiling), as indicated by Onwuegbuzie, Dickinson, Leech and Zoran (2009), were also considered in the study.

The matrix table attached as Annexure I shows how nonverbal communication was recorded in this study. The facilitator always encouraged and asked opinions of quiet members as suggested by Smithson (2000:108) and Creswell (2012:218) to get rich data. In this study, observations helped the researcher to capture adaptation strategies practiced by smallholder farmers during field trips. Photos taken of strategies practiced by smallholders are discussed in Chapter 4.

3.7.3 Key informants' interviews

Key informant interviews were conducted using a key informant interview guide meant to direct the topic (Annexure H). Face-to-face interviews with twelve key informants from LDARD Ba-Phalaborwa Local Municipality were carried out as part of a qualitative data collecting approach to learn about their thoughts on climate change and how the government addresses it. The discussions assisted the researcher in understanding certain government programmes and projects available to address climate change. The conversations also assisted the researcher in understanding the difficulties that prevent officials from providing adequate service to farmers. Findings and discussions in Chapter 4 were obtained from smallholder farmers and key informants who are government officials.

3.7.4 Assessment of level of consensus by focus groups

Since the study was longitudinal, the researcher conducted two observations, one on the farmers' fields and the other during focus group discussions. The purpose of conducting field observation through project visits was to identify adaptation strategies that are already practiced by farmers and to familiarise myself with challenges encountered by farmers. This field observation was done between 2022 and 2023. The purpose of observation during focus group discussions was to ensure that focus group members who failed to voice their opinions but contributed non-verbally were also part of the analysis. Onwuegbuzie et al (2009) believe that the members who are afraid to express their views about the subject under discussion, may be shy, may lack knowledge, which is a limiting factor to their contribution, or may not have been given the opportunity to express their views. In this study, even if farmers had given their views previously, they were allowed to support their agreement through provision of statements. Hence, the matrix table below also shows farmers who participated previously by giving important statements or examples.

Matrix Table 3.2: Assessment of level of agreement between focus group members

Questions	Partici-pant 1	Partici-pant 2	Partici-pant 3	Partici-pant 4	Partici-pant 5	Partici-pant 6
Focus Group 1 (Females)						
Experience of climate change	A	A	IE	A	IE	A
Impacts of climate change on agriculture	IE	A	IE	IE	A	A
Strategies for coping with climate change	A	IE	A	IE	IE	A
Challenges encountered when adapting to climate change	A	A	A	IE	A	IE

A = Agreement by participant (verbal or non-verbal)

D = Disagreement by participant (verbal or non-verbal)

IE = Important statement or example indicating agreement

ID = Important statement or example indicating disagreement

WR = Participant did not agree or disagree (without response)

3.7.5 Questionnaires

Questionnaires are methods used to collect data for large surveys through quantitative research. The researcher developed standardized questionnaire and used combination of closed and open-ended questions (Dawson 2002) and conducted face-to-face interviews as suggested by Green et al (2016) with 50 smallholder farmers from

GRASP Secondary Cooperative. Table 3.3 shows how a predetermined set of questions was developed from the views of participants.

All respondents had an option to choose, but the option of “Other-please specify” was applied as suggested by Dey (2005:16). Mathers, Fox and Hunn (1998) reveal that the collection of quantitative data poses a challenge to participants since they are limited to answer directly to questions asked. The advantage is that the interviewer maintained consistency by asking each participant the same questions in the same way (Mathers et al 1998) and the responses given to each question were the same (Green et al 2016:4). This instrument increased validity and reliability of the results through maintaining consistency.

This instrument helped the researcher to measure the variables to allow data to be used in statistical processes during analysis (Dawson 2002; Creswell 2009). Some of the variables used for analysis purposes are explained in Chapter 4.

The instrument further helped the researcher to answer the research questions of this study as outlined in Chapter 1. Findings from this instrument are discussed in Chapter 4. Saunders et al (2015) further mention that quantitative research is associated with data in the form of numbers which is generated through graphs and statistics as a procedure of data analysis and collection of data through instruments such as questionnaires. The findings discussed in Chapter 4 are displayed in graphs, tables and figures to explain the findings before reading the discussion.

3.8 Process of conducting interviews

According to Teddlie and Tashakkori (1998:229), many researchers combine both interviews and observations in focus groups and present both as qualitative techniques as they focus on open-ended questions and generating narrative data. The purpose of qualitative or in-depth interviews was to give the researcher an opportunity to probe (Saunders et al 2015; Green et al 2016:5) and to understand explanations given by participants and their meanings (Saunders et al 2009:334) The researcher’s aim was to understand the views of smallholder farmers and key informants in the context of climate change and the strategies these smallholders apply to protect themselves. Interviews were conducted for the purpose of developing themes (Paradis, O'Brien, Nimmon, Bandiera & Martimianakis 2016).

The researcher firstly developed an interview guide with a sequence of questions for the purpose of guiding the discussion. The focus group guide consisted of open-ended questions that assisted the researcher to provide direction to the discussion. The focus group guide and questions are attached as Annexure F. The guide comprised rules which were read aloud to participants before the commencement of an interview. Ground rules which kept the discussion on track were read aloud as follows:

- Only one person was allowed to speak at a time.
- One person spoke and finished without being interrupted by others.
- There were no right or wrong answers.
- Maximum participation was required as all views were important
- Participants were requested to not disturb the discussion by putting their phones on silent.
- When participants had something to say, they had raise a hand.
- Participants were not compelled to agree with the views of other people in the group, but they had to maintain respect for others' views.

Secondly, the interviews for the two focus groups were conducted in Gravelotte and Selwana villages. Both venues for interviews were identified and preferred by participants. The interviews with government officials took place in Lulekani Department of Agriculture office. The researcher used a focus group guide and a key informant guide (key informant guide attached as Annexure H) to collect information from the discussions. Although some of the disadvantages of focus group have been noted by the researcher, some participants influenced others through their answers during the discussions (Saunders et al 2015:419). The researcher, as facilitator, adhered to the proposal by Saunders et al (2015:419) and ensured that there was maximum participation by respondents and that the discussion was kept on track (Dawson 2002; Onwuegbuzie et al 2009:4).

In adhering to ethical considerations, prior to conducting focus group discussions, the facilitator outlined the purpose of the focus group discussion. Ethical considerations were discussed in detail under the subheading “recruitment of participants”. Time for discussion was negotiated with participants and did not exceed one and a half hours (Figure 3.5 shows the summary of focus group discussions and times). Participants were advised that they respect this by not disclosing what was discussed in the group to others (Dawson 2002).

The researcher also familiarised herself with facilitator’s roles as suggested by Basch (cited in McLafferty 2004) to avoid bias. The roles are outlined as follows:

- Inspired sharing of views by all participants;
- Ensured that all participants interacted;
- Ensured that crucial aspects of questions or topic were covered;
- Administered probing; and
- Observed and noted non-verbal responses.

The ethical aspects of anonymity, confidentiality and voluntary participation were also guaranteed prior to the interviews. The fact that the interview settings were outside of the neighbourhoods contributed to the confidentiality as no one could hear what was being discussed. The setting was peaceful, cool, and spacious, as well as favourable for discussions (De Chasney 2015).

In addressing these ethical aspects, the researcher used pseudonyms as suggested by Flick (2018:178) to protect participants from any harm. This was achieved through using participants’ names that were not real. For example, FG1P1, where FG1 was used to indicate group 1 of female participants and P1 stands for participant 1 as per the seating arrangement. The findings chapter shows how the pseudonyms were used. Figure 3.5 below shows the seating plan during interviews. The research assistants entered into an agreement with the researcher to not disclose the information collected during interviews. This was achieved through signing confidentiality agreement forms with the researcher prior to data collection. The confidentiality agreement between the researcher and research assistants is attached as Annexure E.

The benefits of the findings of the study were also mentioned prior to interviews. They are discussed in detail in Section 1.8 Significance of the study. Interviewees were requested to sign consent forms if they wanted to proceed with the interview. This is part of ethical considerations and outlined in detail under Section 3.7.2 Participation observation and the approved ethical clearance certificate from UNISA (see Annexure A). During interviews, the researcher started by reading aloud the purpose of the interview and the anticipated length of the interview (Hancock 2006). Each of the two groups were asked this opening question: "*What is the first thing that crosses your mind when I say climate change?"* This was followed by a few general questions that helped the researcher to elicit responses from all individuals in the group (Creswell 2012:218). Creswell (2012) recommends the use of general questions (open-ended questions) by the researcher to give respondents an opportunity to voice their experiences without any interruptions (see Annexures F and H). The researcher adopted and applied the recommendation as advised by Creswell (2012).

Although notes were taken during focus group discussions, the group discussions were also audio recorded to make sure that no information was missed during discussions (Hancock 2006) and to save time since note taking is time consuming. There was an ending question at the end of the discussion as follows*: "Is there anything that you feel was not discussed but important for this topic?"*

After the end of focus group, the researcher developed a focus group summary form. A summary of the subjects discussed was clarified by participants to ensure that their opinions were accurately captured. This validated the credibility of the study as the researcher made sure that participants' information was conveyed correctly (Theron

2015). This process is called member checks or member verification. Member checks are done to allow the audience to judge whether the method was effective in raising the credibility of the results. Soon after the interview, the researcher transcribed the recorded conversation for later analysis and comparison with information from other sources (Hancock 2006) for the purpose of strengthening the findings. Below is the example of summary form of one focus group as advised by Dawson (2009).

Date: 6 April 2022

Venue: Mankosa Thusong Centre

Group: Female Focus Group

Time: 10:00-11:24

Duration: 1 hour 24 minutes

Seating plan of participants

The focus group took place on one of the farms within the location of beneficiaries. The venue was not accessible to other participants, however, the researcher paid for petrol so that those participants were able to reach the venue. The road was not in a good condition, so it was difficult to access the venue.

This group consisted of six females who were smallholder farmers. There were dynamics within the group since some participants claimed to be more knowledgeable than others. Differences between participants resulted in conflicts because every participant's intention was to be heard by others. The overpowered participants were mostly quiet until the researcher intervened seeking their opinion since every participant's opinion was valued. The matrix table Annexure I shows how information was collected from these participants. The lesson learned from this group was that rich or in-depth information was also provided by quiet people. Researchers with a lack of facilitation skills can miss this kind of information.

Themes that emerged from this group were extreme climate events, a lack of resources, and high socio-economic losses. From these themes, the researcher felt that it was necessary to introduce a question that would address the issue of how to improve adaptation at farm level to the next group.

The participants showed an interest to provide more information if required by the researcher. The researcher did not promise the participants anything, however, the researcher promised to share the findings with their leaders who, in this case, were committee members.

Figure 3.5: Summary of focus group discussion

3.9 Data Analysis Procedure

Constant Comparison Analysis (CCA), developed by Glaser and Strauss, was used to analyse qualitative data from the area of the study (O'Connor & Gibson 2003:40). Onwuegbuzie et al (2009) consider this as an appropriate method for analysing focus group data. Careful reading and rereading, coding, displays, data matrices, and diagrams helped the researcher to support the principle of comparison (Boeije 2002). Findings in Chapter 4 discuss in detail how the CCA was used in this study. Through CCA, the data was used to identify different views among participants to find similarities and dissimilarities in what was observed in relation to variables within the sample population (Powell & Single 1996). For Ryan and Bernard (2003), the CCA method considers what is expressed by the same participants or different participants.

The purpose of this analytical tool was to reduce data by comparing units (O'Connor & Gibson 2003). As suggested by Yu and Smith (2021), the method also assisted the researcher to avoid bias through ongoing collection and analysing data from one focus group to another. Glaser and Holton (2004) note that the purpose of this method is to facilitate the development of theory. CCA allowed the researcher to ensure that data supported and continued to support new categories (Cameron 2011). Constantly comparing categories helped the researcher understand the construction of their interrelationships (Scott 2004:114).

Quantitative data analysis was done using statistical techniques and mathematical operations (Tubey, Rotich & Bengat 2015:227). Quantitative data can be analysed through descriptive or inferential statistics (Johnson 2014). In this phase, descriptive analysis is the method used to analyse quantitative data. Descriptive statistics describe, summarise and explain data (Johnson 2014). The researcher used descriptive analysis to describe findings from smallholder farmers without any plan to go beyond the study area as suggested by Dawson (2009). Whilst, on the other hand, descriptive statistics enabled the researcher to ensure that data made sense (Johnson 2014). descriptive statistics allowed the researcher to present data in various ways (Wilson 2014).

Dawson (2002) suggested frequency count or univariate analysis as one way of analysing quantitative data. Univariate analysis means one variable is analysed at a time (Bryman 2012). Whilst Wilson (2014) noted frequency tables, graphs and charts as some of the ways to analyse quantitative data. The reason for summarising data was to give the reader an overview of data before detailed analysis. Diagrams were also part of quantitative analysis because they are easily understood and interpreted (Bryman 2012). Bar charts and pie charts were also used to display data of nominal and ordinal variables. The researcher followed Leahy (2004) to analyse quantitative data using Excel.

Step 1: The excel database was created by typing the name of a survey in the first cell of Row 1 Column A. Each survey question was identified through the creation of column headers which were labelled with Identification Codes (IDs). The same ID on the Column was the same as written on each questionnaire. Since 50 respondents were interviewed, questionnaires were labelled from 1 to 50 as their identification codes.

Step 2: The researcher was to ensure that each response from the questionnaire had a response code number except responses with explanations. For example, responding to gender (variable) question, females were given code 1 while males were given code 2. For a question that needed farmers to choose from answers below, code numbers were given as follows:

Table 3.3: Example of development of questions

Qualitative findings		**Quantitative Instrument**
Qualitative theme	**Participant quotes**	Response codes **(1 strongly disagree-5 uncertain)**
Extreme weather events	"Due to heavy rains experienced early last year (February 2021), the number of pests and diseases increased, and the loss was extremely high." The other farmer added "We failed to plant on time due to heavy rainfall."	Likert response scale (**Question:** Farmers adapt to impacts of climate change) Strongly disagree Disagree Agree Strongly agree Uncertain

This helped the researcher to interpret data through percentages using charts and tables.

Step 3: Identifying code numbers and the response code to each question were entered on the Excel database.

Step 4: Data were analysed and percentages and frequencies were the results.

The qualitative and quantitative results were integrated and presented using a joint display. The joint display assisted the researcher to interpret, conclude and provide recommendations about the findings of the study. The joint display allowed the researcher to display both qualitative and quantitative findings to ensure that integrated findings were satisfactory (Haynes-Brown & Fetter 2015). Guetterman, Fabregues and Sakakibara (2021) recognise the benefits of joint visual display as ensuring that findings between two methods are improved due to strengthened transparency. Guetterman et al (2021) also observe that researchers can display joint data in the form of a matrix, graphs, models, figures and others. The results from the findings are presented in Chapter 4 using joint display.

3.9.1 Data transcription

Transcription is the first stage in data analysis (Gale, Heath, Cameron, Rashid & Redwood 2013:4). Transcription reproduced the spoken words from an audiotaped interview into written text (Halcomb & Davidson 2006:38). Transcribing helped the researcher to convert the audio recordings of interactions with participants in a written form (Halcomb & Davidson 2006:38, Cope 2017; Thorsten, Thorsten & Christian 2015). The advantage is that the process enabled the researcher to make data easier to analyse. The researcher adopted advice by Azevedo et al (2017) of transcribing using paper, pen and pencil.

Transcription guidelines assisted the researcher to systematically organise data before analysing text and ensured that transcripts were consistent (McLellan, MacQueen & Neideg 2003:64). Non-verbal communication, such as laughter, sighs, emphasis, and others, were transcribed as they give a meaning when interpreting the text (Cope (2017). Nonverbal communication is defined by Hess (2016:208) as a way of communicating without expressing any words.

Non-verbal communication strengthened and added value to the data analysis as suggested by Doody, Slevin and Taggart (2013). For example, non-verbal communication recorded during the discussions with focus group participants was laughter, smiling, nodding of head (from side to side and up and down), expressing emotions (for example, facially, with a loud voice).

The researcher did not disclose the identifying information during transcription (Hancock et al 2009). For example, the name of person raised by focus group member during discussion was replaced by a pseudonym, such as Focus Group 1 Participant 1 (FG1P1). This meant that the participant was in group 1 which was the group of females and participant 1 as per the seating during discussions.

For example, during the discussion, after a comment by one of the participants, others nodded their heads as a sign of agreeing with what the participant had said. This information could have been missed if it was not recorded during the group discussion since it cannot be transcribed from an audio-recording. On the other hand, field notes cannot be replayed as audiotapes (Tessier 2012). See Table 3.4 for transcription guidelines and transcription symbols below in Table 3.5.

Table 3.4: Transcription guidelines

Irrespective of whether the information is incorrect, the transcriber should write exactly what participants say.
Interjections like mmm. mhmm, okay, yeah and others need to be included.
Nonverbal communication to be included in present tense (for example, laugh, sigh, quietly).
Repetition of words excluded but words with emphasis were included
Identification information changed
Writing numbers less than ten in words and above ten written in numbers
Words with emphasis included in capital letters
Interviewer marked by I and respondents by FGM (1,2,3,4,5,6)

Table 3.5: Transcription symbols and their use

Commas (,) used for short pause of about 1-3 seconds.
Ellipses (…) used when participants have a longer pause above 3 seconds.
(pauses) use this symbol if pause is long (above 3 seconds) and in the middle of a sentence.
Em dash (-) used to show that the speech is changing. No space is allowed before and after Em dash.
Underline (_) used to emphasise certain words.
Brackets used to show words not mentioned by participants but included in the transcription.
Quotes “” used to demonstrate words said by someone.

Not all the guidelines and symbols above were used in this study. The study focused on the guidelines and symbols that were observed during the discussions. Some of the transcription guidelines, such as non-verbal communication examples, recorded during discussions were smiling, nodding of head side to side (meaning not agreeing with what has been said), nodding of head up and down (meaning agreeing with what has been said).

3.9.2 Familiarisation with data

The second stage was that of familiarising with the data. In this stage, the researcher and the research assistants listened to audio recordings, read transcripts and field notes several times to familiarise themselves with the data. Gale et al (2013) and Wilson (2014) regard this stage as critical as it is part of the interpretation of data. As field notes, transcripts and audio recordings have disadvantages (Tessier 2012), reading the transcripts, field notes and listening to the audio recordings several times assisted the researcher and research assistant to identify themes and patterns in the data (Wilson 2014).

As transcripts were re-read and contextualised, quotes expressing ways of imagining a particular phenomenon were identified as brief interpretations of constructs and manually assigned to themes and sub-themes as mutually agreed by the two researchers (Boltong, Ledwick, Babb, Sutton & Ugalde 2016). The researcher read the transcript line by line (Gale et al 2013) applying codes which described the important interpretation by smallholder farmers in that paragraph. This was done through highlighting important sentences during transcript reading (Theron 2015) which are aligned to research questions and research aims of this study. In this stage, open coding was recognised and prioritised as it contained critical information from participants' points of view (Gale et al 2013).

3.9.3 Coding

Coding is the process of disconnecting and conceptualising data for data analysis (Santos, Cunha, Adamy, Backes, Leite & Sousa 2018). Coding purports to define and identify interconnections between data (Santos et al 2018) and is regarded as the first stage of theory development. Charmaz (2006) views coding as the first step of making analytical interpretations from statements emerging from data. She further states that coding helps the researcher to understand the meaning of the data mean.

Codes are designed by researchers with the purpose of capturing primary data (Theron 2015:4) and connecting data to an idea. Coding helped the researcher to save time during the analysis of data (Wilson 2014).

With coding, the researcher managed to move from empirical data to research findings (Linnerberg & Korsgaard 2019). The researcher adopted Linnerberg and Korsgaard's (2019) style of picking up terms used by participants during focus group discussions as codes to be close to the data and to avoid utilisation of researcher's words to improve validity and authenticity.

Phase 1: Open coding

Open coding was done to give the researcher an opportunity to enable her to select and focus on specific concepts of the social problem (Glaser 2016:108) of this study.

In open coding, at the beginning, the researcher examined data line by line using constant comparison for generation and clarification of codes (Given & Saumure 2008). Later, data were examined sentence by sentence. Memon, Umrani and Pathan (2017) maintain that, at this phase, transcripts are read to identify themes and concepts occurring more than once. At this phase, I started with reading several times and studying all information including transcripts, observations, and field notes as recorded during focus group discussions with the purpose of understanding what has been said (Boeije 2002) and then labelled relevant information with codes which are words that were used by focus group members during discussions.

By assigning codes, the researcher was able to understand the meanings and actions as provided by the participants. The researcher used different colours to highlight some words that reflected participants' views. This assisted the researcher to group similar words together in the axial coding. Through open coding or initial coding, as defined by Charmaz (2006) and Bailey (2008), the researcher was able to develop the core conceptual categories. It must be noted that not all data were coded, however, the researcher coded the data she thought was useful for analysis, as advised by Bailey (2008).

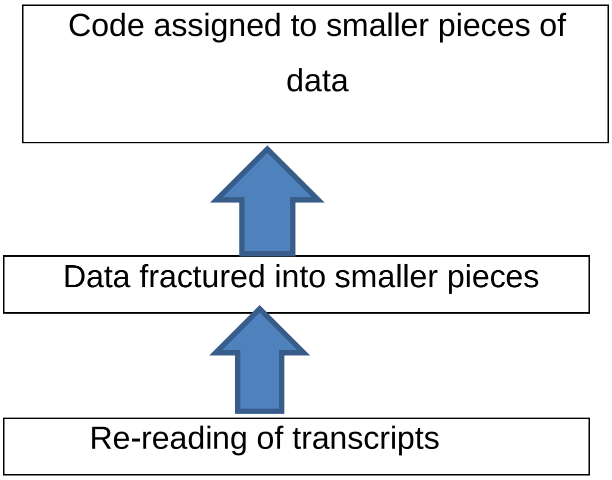


Figure 3.6: An example of how codes were generated from female focus group discussion

I: What are your experiences about climate change?

FG1P1: *You know, we farmers are suffering. To produce more, we are controlled by weather. Climate change affects all our plans. We even do not know what to do. The planting seasons have changed because the patterns of rainfall have changed also. Some years ago, it used to rain and water availability was not a problem. But now, not to mention farming, there is even shortage of drinking water.*

I: So, how do you farmers survive in farming business without water?

FG1P3: *Indeed WATER is a serious problem to farmers because we cannot produce without water. We plant but only to find that the water for irrigating crops is not enough. I just plant few crops to be catered by the water that is available.*

FG1P6: *What she means is that we don't have choice but to plant few crops which are not sufficient for us for both consumption and marketing.*

FG1P2: *Even the high temperatures this nowadays may be occurring because of climate change. The area is dry, and we experience several dry periods. If am correct, every year, if not after two years, we have drought in this area. This is where we need support than before from government* (The respondent looked at others for approximately ten seconds with his frown face and said:) *our government does not assist us* (frown face).

FG1P4: *Mmmmm (negative), you haven't seen what happened to us in February 2020. It RAINED, RAINED, RAINED from the beginning of the month until the end* (….). *We prepared the soil but never planted. We lost money for ploughing, money for seedlings and it was tough.*

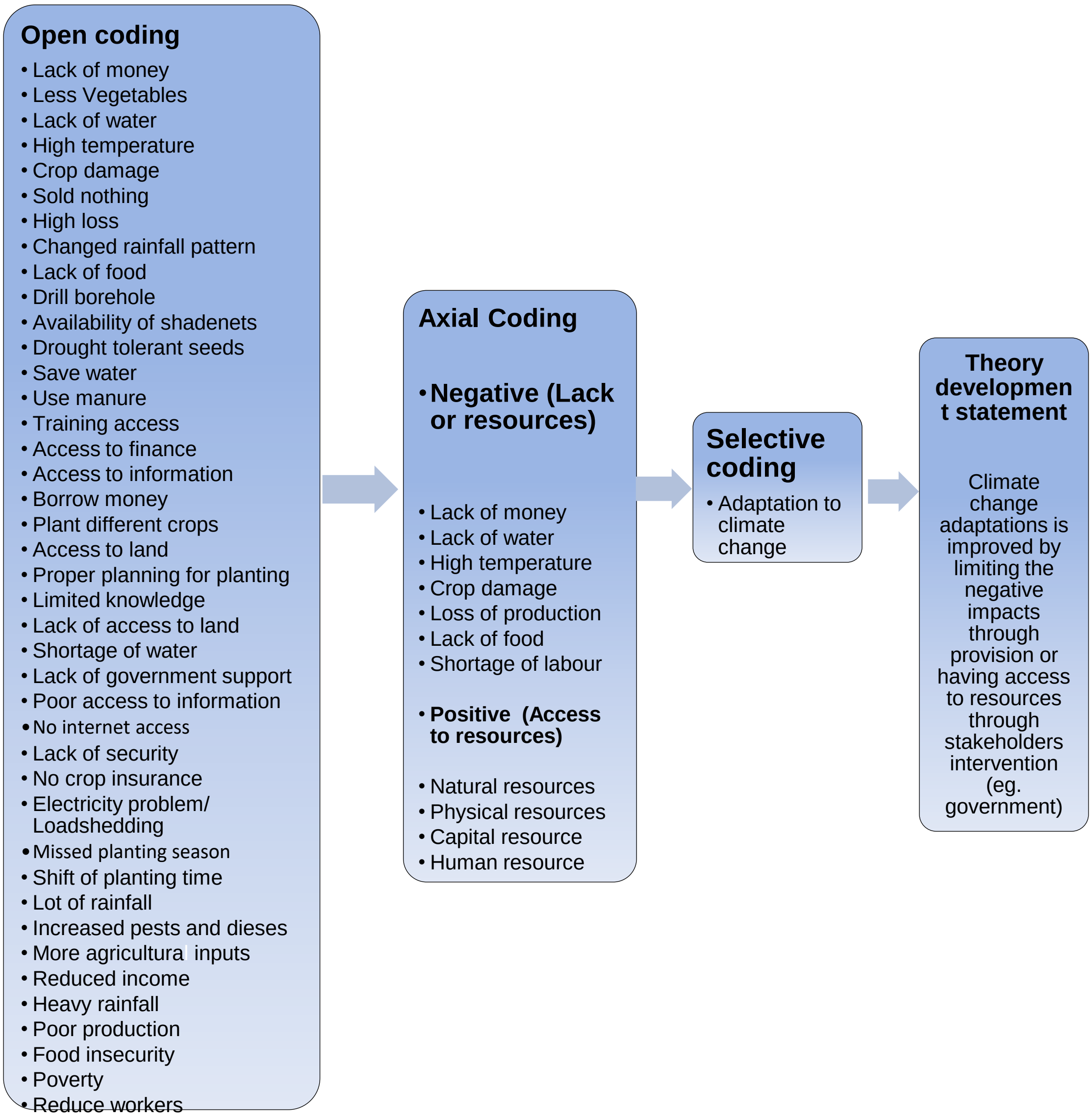


Figure 3.7: Open to selective coding data

Phase 2: Axial or Focused Coding

Axial coding is the process of improving large amounts of data as developed from the open coding (Charmaz 2006) with the aim of identifying the correctness of codes from open coding. During this phase, the researcher grouped the data that was scattered from open coding to allow the emergence of categories (Given & Saumure 2008). By doing this, the researcher was able to provide explanations about the phenomena researched in this study (Santos et al 2018) which is climate change. In this phase, axial coding connects categories and subcategories and explores their connections (Charmaz 2006).

This phase allowed the researcher to identify relationships between codes and their connections (Given & Saumure 2008; Saunders et al 2009) by grouping like codes from the open coding phase. Through axial coding, the researcher chose categories which she thought were relevant to address the research questions (Flick 2009:312).

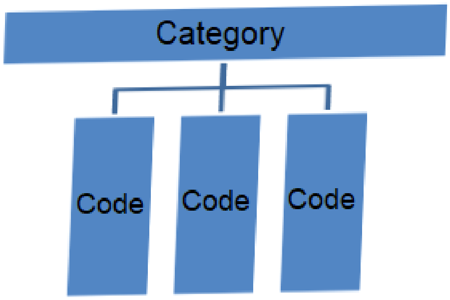


Figure 3.8: Example of codes from opening coding for development of category

In axial coding, the researcher used a coding paradigm which allowed her to identify the central category about the phenomenon, conditions which were causing the occurrence of the phenomenon, strategies or actions resulting from the phenomenon, factors influencing the strategies and the ways of reducing the consequences of the phenomenon (Creswell 2013).

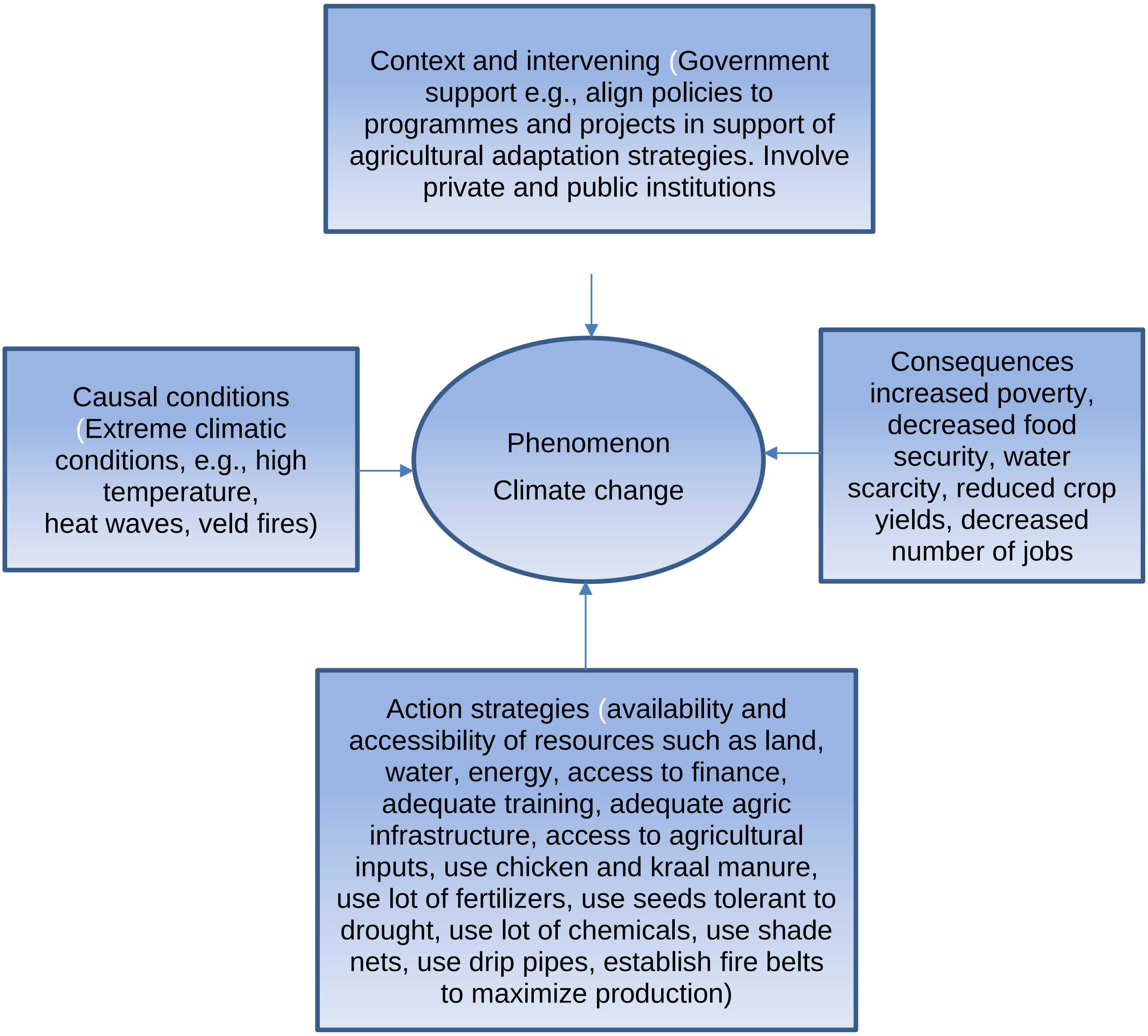


Figure 3.9: An example of coding paradigm from obtained data

Figure 3.8 depicts the causes of climate change as high temperatures, heat waves, and veld fires. Climate change causes have a negative influence on several sectors, including water, agriculture, energy, and the social sector. The implications of climate change are increasing poverty, decreasing food security, water shortages, lower agricultural yields, and a reduction in the number of employees in different industries, including agriculture. The action to lessen these repercussions is the availability and accessibility of resources from institutions such as energy, finance, water, agriculture, and training. To mitigate the impact of these behaviours, private and public entities, including government, must intervene through policies, programmes and through the provision of funding.

Phase 3: Selective coding

The process of making a choice in selecting a core category and relating it to other categories from axial coding is selective coding (Vollstedt & Rezat 2019). This phase allowed the researcher to analyse how the core category affected other categories emanating from axial coding, and how axial categories affected the core category. Categories generated from the axial coding were connected to one core category. Vollstedt and Rezat (2019) define this as selective coding. The goal of selective coding is reached when results from axial coding are discussed, merged and validated.

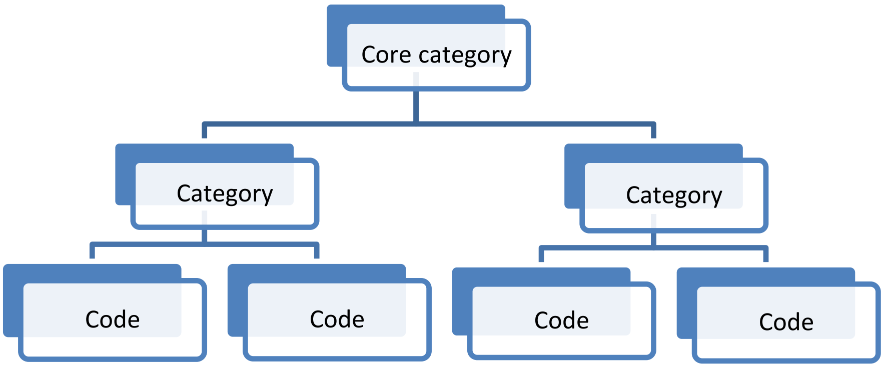


Figure 3.10: Example of hierarchy for development of core category

Figure 3.10 shows how the core category (theme) was developed. Participants' quotes were coded, and similar quotes were grouped and coded to form categories. Categories were grouped and coded to form the core category.

3.10 Ethical considerations and Field Research challenges

Ethics covers what researcher should or should not do when conducting their research (Cohen et al 2018). Dube, Ndwandwe and Ngulube (2013:16) define ethics as the moral correctness of a specified conduct as it includes social responsibility that refuses to accept needless human suffering and exploitation. Blandford (2013) notes that ethics are concerned with addressing issues that may cause harm to participants who contribute to the study. He further mentioned that the processes of obtaining ethical clearance are necessary to protect the rights of participants.

The objectives of ethics in research are to make sure that humans who participate in a study are protected and that research carried out addresses the needs of people, groups and societies. Ethics assist researchers to study research activities and projects for their ethical soundness by looking at issues such as the management of risk, protection of confidentiality and the process of informed consent (Easterby-Smith et al 2015:409) (see the consent form attached as Annexure D). Leedy and Ormrod (2014: 273) argue that the researcher should obtain permission from the appropriate committee from the institution for any research involving humans. This research involved qualitative data collection which required ethical approval before conducting the study. The ethical certificate is attached as Annexure A.

The research adopted an ethical framework as suggested by UNISA. According to Bryman (2012:140), researchers receive the informed consent of individuals participating in research by getting them to sign informed consent forms. The purpose of consent forms is that they give the respondents the chance to be informed about the nature of the research and the implications thereof (Bryman 2012:140). In adhering to the ethical framework of the university, the researcher's permission was granted by UNISA. Gatekeepers from GRASP and LDARD also granted permission. The permission letters to conduct the study are attached as Annexures B and C. The participants also granted the researcher permission to conduct the study through signed informed consent for protection of their identities (Bryman 2012:137) and allowing them to withdraw from the study at any time.

Due to the outbreak of COVID-19, risks were anticipated by both the researcher and participants. However, precautionary measures, such as maintaining a social distance of at least two metres, temperature recordings, register of participants, sanitising, and wearing masks were applicable to all participants and the researchers as required by UNISA COVID-19 guidelines to limit the spread of this virus. The researcher adhered to the UNISA COVID-19 guidelines which stipulated processes and procedures to follow when collecting data during COVID-19. The researcher also adhered to governmental directives to ensure that the reputation of the University was protected. All the directives, as outlined by government during and after interviews, were followed.

Despite the fact that the research was done in an ethical way, it was difficult to contact GRASP participants during the COVID-19 pandemic in April 2022. This was the most challenging moment for the researcher. As a result, the researcher encountered a problem with over- and under-coverage during participant selection (Bethlehem 2009).

Because of these difficulties, the sample size for this study was lowered. The researcher intended to interview 10 government officials and 78 smallholder farmers, according to the proposal. The actual number of interviewees was 74, with 12 smallholder farmers participating in two focus group discussions and 12 key informants for the qualitative phase and 50 smallholder farmers providing quantitative data responses.

Planning for data gathering was difficult because most participants did not want to meet with other individuals. COVID-19 was a new illness that killed many individuals, including some smallholder farmers that had been pre-selected to participate in this research. Data were gathered at alert risk level 1 since the researcher believed it was the safest time as restrictions were relaxed.

3.11 Chapter summary

This chapter discussed both the study area's description and its socioeconomic aspects. The justification for the pragmatic paradigm, mixed method approach, and design were discussed. The chapter included and discussed the study population, sampling criteria and methods, data collection and analysis methods, and procedures. This chapter also detailed how the researcher dealt with ethical and methodological obstacles while conducting the research. The next chapter will present the findings of this study.

CHAPTER 4: SMALLHOLDER FARMERS' EXPERIENCES, IMPACTS, CHALLENGES, AND ADAPTATION STRATEGIES TO CLIMATE CHANGE

4.1 Introduction

This chapter presents findings from both primary and secondary data sources such as government publications and statistics reports (policy documents, yearly reports), and journal articles discussed in Chapter 2 to understand the concept of climate change from international and local countries.

The chapter further presents and discusses the profile of farmers, their experiences about climate change, their challenges, exposure and response to these impacts. The last section in this chapter is the chapter summary.

4.2 Document analysis

The study of documents aided the researcher in gathering data relevant to climate change. This enabled the researcher to gain insight into the climate change arguments. Through document analysis, climate change was comprehensively investigated locally and internationally. The current status of climate change in South Africa was elicited from document analysis. This study relied on government publications and statistics reports (policy documents, yearly reports), journal articles, conference reports, and other materials. The goal was to compare data from documents with data from research interviews in order to answer some of the research questions such as "what are the causes of climate change?" as outlined in Chapter 1 of this study.

4.3 Secondary data findings

The findings from books, journals, policies, and reports aided the researcher in answering the study's research questions. This section discusses the findings from literature on climate change and smallholder farmer adaptation options. The findings from literature demonstrated that climate change is real, hazardous, and continues to damage people's lives in both developed and developing countries. Climate change threatens human lives (Klein et al 2014) by the same amount that temperatures are anticipated to rise by certain degrees. Agriculture, water, and energy sectors, which are important to human life, will be disproportionately affected by global warming, which is influenced by population expansion, which, in turn, increases people's needs (Michie & Cooper 2015; Shahzad 2015; Akhtar 2019).

According to projections, global temperatures are expected to rise causing some areas of these countries to experience drought, while others may have ample rain. Mali's desert area, for example, may face drought, threatening the country's food security (Godfrey & Tunhuma 2020). According to research findings, food insecurity has been another challenge brought on by extreme climatic conditions.

4.3.1 Human contributions to climate change

Natural and human causes are impacting climate change worldwide, including South Africa. However, this study shows that human causes contributed more than natural forces (Michie & Cooper 2015). The study identified population increase, agriculture, land degradation, deforestation, and mining as significant reasons for climate change. These variables contribute significantly to GHG emissions, which is why the climate is warming. The link between these elements has also been determined. For example, expanding population raises demand for services, such as food, energy, housing, and water, which causes land degradation, high evaporation, and soil moisture loss, resulting in variability in rain and temperature patterns. Due to high temperatures, water sources, such as rivers, have dried up making it challenging for farmers to irrigate crops. As a result, extreme weather events like droughts and floods occur, wreaking havoc on farmers' livelihoods and infrastructure.

For example, the 2022 tropical cyclone caused flooding that harmed hundreds of thousands of people in African countries, such as Mozambique and Madagascar, destroying infrastructure, shelters, schools, health care facilities, bridges, and other structures. High temperatures in Mali lowered cassava tonnes due to water resource stress, which affected crop yields (Clarke, Otto, Stuart-Smith & Harrington 2022).

The literature reviewed showed that individuals, communities, and countries respond to climate change through mitigation and adaptation. For example, the UNFCCC and Paris Agreement emphasise the need for countries to reduce GHG emissions and to adapt to climate change. The conventions also reveal the urgency of responding to climate change (UNFCCC 2007). Crop and livestock production were found to contribute significantly to GHG emissions, which influence the temperatures (Holowitz & Gottlieb 2010). Agriculture must shift from being a part of the problem to being a part of the solution (FAO 2021). To address the effects of climate change, the literature reviewed suggested several options that smallholder farmers could adopt and implement to cope with impacts of climate change.

4.3.2 Mitigation and adaptation as a response by farmers

Agricultural crop residues burnt after harvesting by smallholder farmers contribute to severe climatic conditions such as high temperatures (DAFF 2015). While smallholder farmers contribute to GHG emissions, they also play an important role in climate change mitigation and adaptation. Instead of burning agricultural crop residues, smallholder farmers can feed them to their animals or leave the residues on the land to improve the soil quality. Residues can also be used to produce energy (FAO 2011). For example, leaving the residue after harvesting aids soil erosion control and soil moisture retention. Agricultural residues are fertilisers that can enhance soil quality (UK DEFRA 2010). Effective field residue management can also improve irrigation efficiency (Maurya, Bharti, Thokchom, Singh & Pratap 2020). Some of the leftovers, such as tomato waste, can be processed and transformed into other goods like tomato paste, tomato sauce, etc. Through processing, more jobs can be created whilst farmers also have additional income.

Sustainable manure management entails a reduction in the rate at which inorganic fertilisers are applied while still using manure nutrients effectively to nourish crops and grasslands (FAO 2008). This is a shift away from seeing manures as waste and emphasising their usefulness as organic fertilisers. Farmers can reduce GHG emissions through livestock management, crop residue management, and soil management (Holowitz & Gottlieb 2010). The findings revealed that biogas produced from livestock manure can address the energy crisis currently faced by the country.

GHG emissions can be reduced by using feedlots where livestock are not allowed to wander freely on land. Livestock faeces were shown to be a source of GHG emissions and water pollution. It is therefore advised that waste management in the form of maintaining livestock in feedlots and establishing manure storage is practiced (Bradley 2019). The advantage of manure is that it may be put to the field before planting to improve soil fertility and reduce fertiliser expenses.

The findings of the literature revealed that planned adaptation, which requires government intervention through policies, programmes and projects, are strategies available at global and country levels to adapt to climate change. Autonomous adaptation, which requires no intervention, is also practiced by farmers at farm level. Land extension for rice production originated as a way for increasing rice yields in Indonesia (Godfrey & Tunhuma 2020). Other techniques adopted by farmers in Indonesia included increasing inputs and enhancing the degree of technology (Nkamleu 2011). “Legowo” and “tabela” were discovered to produce superior agricultural outcomes while decreasing the planting season and increasing harvesting time owing to sowing seeds (Kusumasari 2016).

Due to the country's water scarcity and land shortage issues, the construction of wells and ponds near to rice fields is an increasingly common strategy employed by farmers in Indonesia (Nughara 2013). Ponds aid farmers in storing water throughout the summer and collecting water during wet seasons. Farmers prioritise planting crops such as cassava and sago, which require less land, fertiliser, and water than rice, which requires more area and more water (Nughara 2013). Farmers also use innovative irrigation equipment, such as sprinklers and drip irrigation to save water.

Due to crop production losses caused by climate change, some farmers opted for non-agricultural activities that include carpentry and selling non-agricultural items, such as handmade goods and processed foods, as an income diversification strategy (Nughara 2013). This approach is an extra source of revenue and was mostly used by farmers after harvesting their crops. To combat common pests and diseases, farmers employed household items such as laundry detergent, bleach, and fragrances.

Farmers' strategies in Mali use free agricultural innovations, for example, sowing seeds. These efforts include enhanced seed preparation, water collecting, and organic fertiliser application. Sowing millet and sorghum seeds increased their agricultural production. Water shortage was also shown to be a problem in Malawi. Farmers construct water collection structures, such as earthbunds and zais, to solve this challenge (Aune 2008). These structures provided a dual function of preventing crop failure and conserving water. Other farmers used green fences, grass strips, natural regeneration, and planting legumes and grains to improve land management. Farmers in Mozambique and Zimbabwe change crop varieties as a strategy to adapt to climate change (Chichongue, Karuku, Mwala, Onyango & Magalhaes 2015).

Smallholder farmers in Mozambique also practice crop rotation (Filimone et al 2014). Non-agricultural activities are a common strategy in Mozambique and Indonesia. For example, the production and selling of charcoal during years of inadequate revenue from agriculture is a strategy adopted by Mozambican smallholder farmers (Martinho & Kreisler 2010). This short-term coping strategy for managing the present climate events may limit the availability of long-term livelihood options as it can intensify soil erosion leading to flooding. Monjane et al (2018) highlight that this strategy is an obstacle to economic growth and food, and government might experience challenges in the long run to solve this.

In Africa, the invasion of pests in many African countries, including Mali, destroyed many hectares of land, leaving Africa food insecure (Besada & Sewankambo 2009). From these findings, it is clear that smallholder farmers from different countries were negatively impacted by climate change impacts and lack adaptive capacity. The findings also revealed that food availability and scarcity are determined by climate change.

To address the effects of climate change, the literature suggests several options that smallholder farmers could adopt such as changes in planting dates, diversification to other crops, adoption of drip irrigation and sprinkler pipes, application of agricultural inputs such as fertilisers and chemicals, utilisation of various cultivars, and borehole drilling. Even if the recommended strategies are available, not all smallholder farmers adapting due to other factors such as a lack of: climate information, resources such as water and energy, access to credit, access to land, water and belief in the reality of climate change. These factors are discovered to be impediments for smallholders in implementing available recommended strategies.

Although the UNFCCC-led conventions provide international support for mitigating and adapting to the effects of climate change by requiring countries to sign agreements (UNFCCC 2007), smallholder farmers are still unable to adapt to climate change due to barriers that prevent them from adopting and implementing climate change strategies. Farmers' ability to adapt to climate change can be hampered by a lack of political will in terms of policy development and a lack of resources such as credit and extension services (Adger et al 2007). For example, according to UNFCCC objectives, developed countries are supposed to provide funds to developing countries. This demonstrates that developing countries are unable to address the effects of climate change and further confirms why smallholder farmers are having difficulty adapting to climate change.

4.4 Socioeconomic profile of smallholder farmers

The results show that there are socioeconomic factors influencing the vulnerability of smallholder farmers to climate change. These factors include age, gender, level of education, farm size and source of income. These factors also determine how effectively farmers can manage climatic stresses that affect their livelihoods and their choices of adaptation strategies to implement. Furthermore, the determinants influence farmers' exposure to climatic events, sensitivity to exposure, and ability to adjust to these events. of this method aided in the development of statistics for the goal of integrating these findings with the quantitative data to obtain the mixed approach.

Table 4.1: Redistribution of respondents according to gender

Item	Frequency (f)	Percentage (%)
Question 1: What is your gender?		
Male	31	62
Female	19	38
Total number of frequencies	fx=50	100%

Although the study was not gender based, Table 4.1 indicates that 19 (38%) of the participants practicing farming in the area of the study are women and 31 (62%) are men. The importance of gender has been noted from the point of agricultural production and allocation of resources (Rwelamira 2015). Females have been marginalised in terms of allocation of resources which affects their livelihoods as they depend on natural resources such as land.

The study findings agree with Nellemann, Verna and Hislop (2011) that power is a socio-cultural and political barrier in terms of land allocation between females and males. Unique-Kulima (2017:3) revealed that, with reference to security and access to land, females are more marginalised than males.

The sociocultural and political dimensions of unequal allocation of resources push farmers to farm on small plots which hinder them from reducing the impacts caused by climate change (Deressa, Hassan, Alemu, Yesuf & Ringler 2008:10). This implies that, since the power relations between females and males are different in accessing and controlling assets, their adaptive capacity is also different (African Development Bank 2011).

Table 4.2: Participants and age group

Item	Category	frequency	Cumulative	Total %
Question 2: Which age group do you belong to?				
≤35	Youth	8	8	16%
36-60	Middle aged	35	43	70%
<60	Old	7	50	14%
Total		fx=50		100%

Age plays a significant role in farming. Hence, age analysis was done to record the age group of farmers in the area of the study. Table 4.2 above presents the distribution of farmers' ages in this study. The findings reveal that 70% of the farmers who are involved in farming are in the middle-aged group between 36 and 60 years old. Eight (16%) farmers are youth less than or equal to 35 years. This is because of a lack of interest in farming and other opportunities for the youth in Limpopo Province (Maponya & Mpandeli 2012). Seven (14%) participants involved in farming are above 60 years. This research supports Kusumasari's (2016) findings that extreme weather events deter young people from working in agriculture. Nhemachena and Hassan (2007) agree that age can encapsulate farming experience.

According to HelpAge International (2015:6), the knowledge and farming experience that is possessed by older people can improve agricultural production and reduce environmental destruction simultaneously. Older people's knowledge of weather patterns is vital to respond to climate change impacts.

Different age groups indicate that adaptation can be a challenge in the area of the study as there are few old farmers who are knowledgeable and have experience in reducing the impacts of climate change. However, age cannot conclude that farmers have experience in farming and knowledge to deal with effects of climate change. There are farmers who are below middle age who have exposure to climate information, and they contribute significantly to the adaptation to impacts of climate change. For example, youth are more likely to find off-farm work opportunities during extreme weather disasters, making their income less vulnerable (FAO 2024) due to their exposure to education.

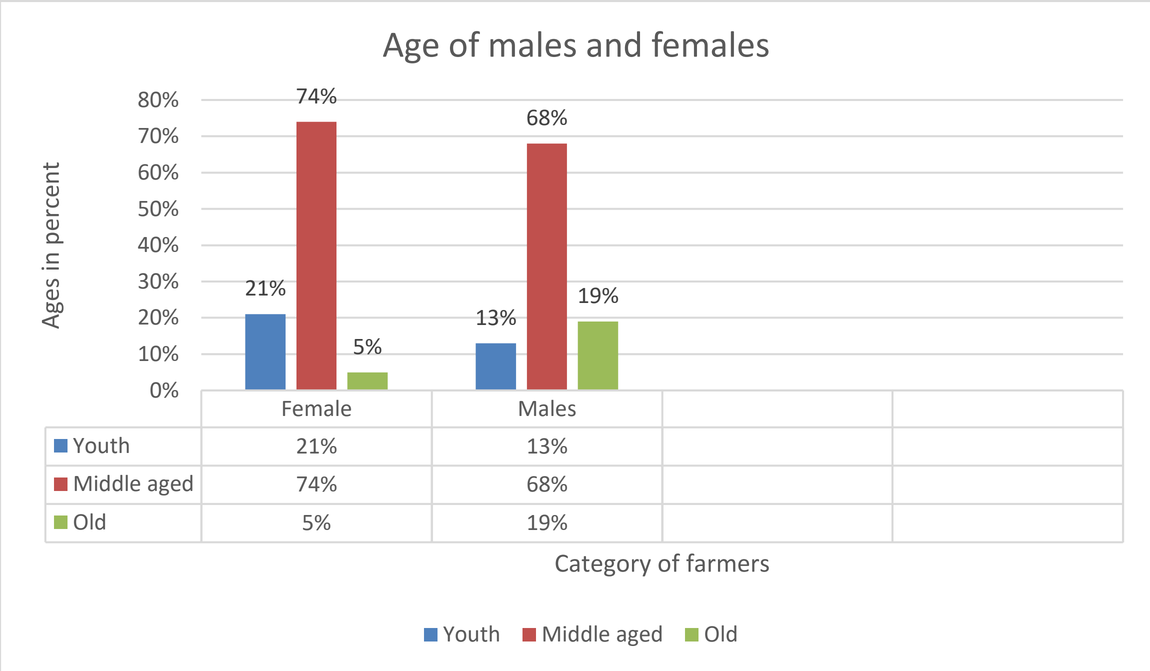


Figure 4.1: Age of respondents by gender

Table 4.3: Redistribution of education of participants

Item	Category	f	Cumulative	Total %
Highest qualification				
No schooling	No education	4	4	8
Primary	Low	14	18	28
High School	Middle	16	45	32
Tertiary	High	16	50	32
Total		fx=50		100

Table 4.3 presents farmers' levels of education. Findings from the table indicate that the majority of farmers, thirty-two percent (32%), have completed high school and tertiary education. This is followed by twenty-eight percent of farmers (28%) with primary education. Eight percent (8%) have no schooling.

The research found that education increases the ability of farmers to obtain and apply relevant information concerning the changing climate, which increases their farm level adaptation options. Hence, it is one of the factors that influence farmers to adapt to climate change. Maponya and Mpandeli (2012) found that education influenced farmers to decide whether or not to adapt to climate change. Falaki, Akangbe and Ayinde (2011) agree that a farmer with a high level of education has a different perception than one with a low level of education.

Low education levels limit off-farm employment opportunities and hinder the ability to start and expand businesses, leading to unstable, informal, and low-paying jobs for vulnerable groups (FAO 2024). This suggests that farmers who rely on farming for a living, particularly those with little or no education, may be more sensitive to climatic challenges, limiting their ability to adapt. Climate change may worsen educational disparities by causing economically marginalised farmers to remove their children from school due to extreme weather occurrences (FAO 2024). This is a maladaptation strategy since, with education, farmers' children will be more prepared to survive the threats that climate change may bring in the near future.

Farmers with high levels of education have an advantage in that they have access to climate knowledge and are exposed to many more adaptation possibilities for climate change than farmers with low or no education. According to the literature, Indonesian farmers with agricultural qualifications failed to maintain crop quality and quantity due to the frequency and recurrence of extreme climatic occurrences, such as droughts and flooding, which created waterlogging in their fields (Kusumasari 2016). However, as climatic hazards are recurring, these farmers have the choice to work off-farm to decrease their exposure and vulnerability to the effects of climate change. They have a chance to recoup their revenues and survive the effects of future weather disasters.

Ongoing education is a prerequisite to improve adaptation skills of farmers as climate change continues.

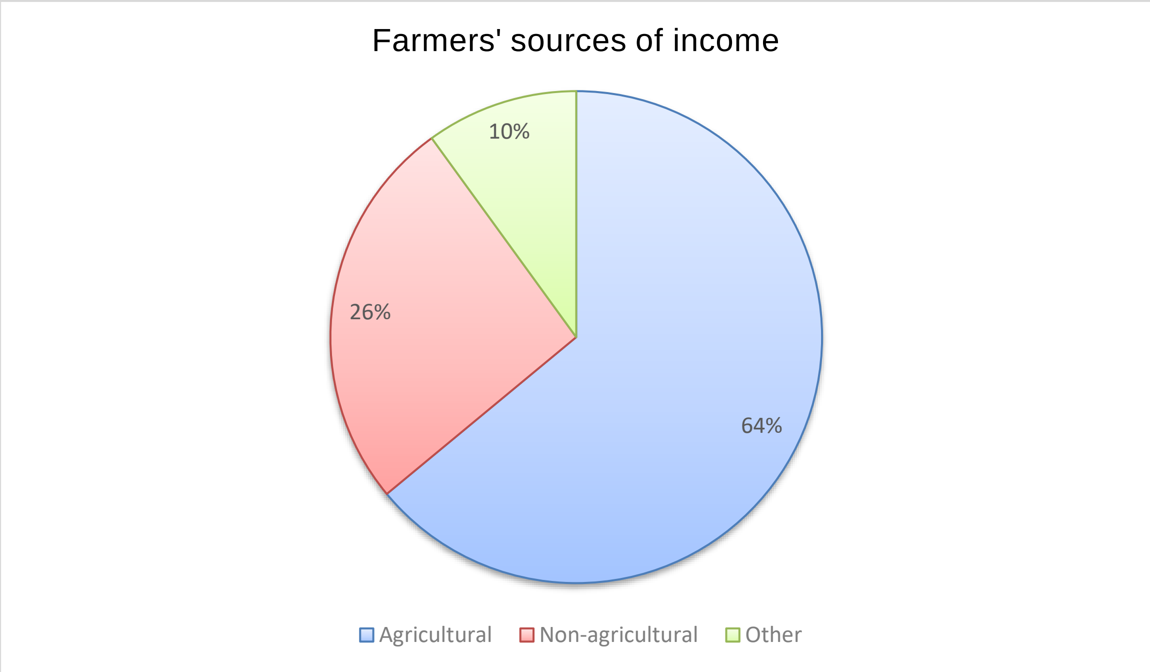


Figure 4.2: Distribution of farmers according to their sources of income

Agriculture is both the source of food and income and the driver of reducing poverty especially for poor farmers residing in rural areas. The protection motivation theory discussed in Chapter 2 is concerned with how and why farmers protect themselves from climate threats. Figure 4.2 above presents farmers' sources of income that reduce vulnerability and farmers' exposure to various climatic hazards thereby improving their livelihoods. From the livelihood perspective, the availability and accessibility of assets, such as finance, assist farmers to recover from shocks of climate change. Sixty-four percent (64%), a majority of the farmers, depend on agriculture as their source of income and twenty-six percent (26%) indicated their source of income as non-agricultural. Ten percent (10%) of farmers indicated their source of income as grants.

The findings imply that farmers who derive their additional income from non-agricultural activities have a better chance of surviving the effects of climate change while farmers whose primary source of income is agriculture or grants have a low chance of surviving climate change shocks in the near future due to their exposure to the area's climatic risks. Furthermore, farmers with non-agricultural income may invest in farming operations that may increase their agricultural production. For example, farmers who invested in boreholes and can afford to pay for electricity, which is connected to their shade-nets, can increase their production. Reduced agricultural production in rural areas can lead to decreased farm incomes, higher food costs, unemployment, and migration (FAO 2022a). For example, some climatic hazards, such as drought, may have a long-term impact on vulnerable populations' agriculture revenues.

Achieving a good qualification may be the motivation for farmers to work in a non-agricultural setting and earn additional income.

Farmers who work off the farm have an opportunity to invest in farming if the investment helps them to maintain or increase farm production and raise their overall income (Hennessy & O'Brien 2008). They can also improve their total income by investing some of their off-farm income in labour-saving equipment if the cost of their labour exceeds the investment needed. Off-farm income can alleviate financial limitations encountered by farmers. Farmers who rely only on farm income must use a larger proportion of farm profit to meet their consumption needs (Hennessy & O'Brien 2008). Non-farm income possibilities in rural areas can broaden the reach of financial services, such as loans, for farmers and agri-food businesses (FAO 2024).

Table 4.4: Distribution of farmers according to their farming experience

Item: Years of farming experience	Category	F		Female/Male %		Cumulative	Total %
Number of years		Female	Male	Female	Male		
>6 years	Low	7	7	37	23	14	28%
6-10 years	Moderate	8	10	42	32	32	36%
<10 years	High	4	14	21	45	50	36%
Total		fx-19	fx=31	100	100		100%

Data presented on Table 4.4 show that 18 out of 50 farmers (36%) have six to 10 years and more than 10 years' experience in farming. These farmers are regarded as having moderate and high farming experience as indicated on the category column. Fourteen out of 50 farmers (28%) are considered as having low farming experience.

Experience in terms of gender shows that the number of males with high farming experience above ten years (10) is greater than the number of females within the same category. Males and females within the high category contribute forty-five percent (45%) and twenty-one percent (21%) respectively. The table above also indicates that females dominate in terms of years in farming between 6 and 10 years, as compared to males. Under the moderate category, the percentage of female farmers with 6 to 10 years farming experience is forty-two percent (42%) and males are thirty-two percent (32%). Females dominate with thirty-seven percent (37%) against males who have twenty-three percent (23%) in the low category of farming experience of fewer than five years.

The data show that more farmers have been in the farming industry for at least six years than farmers with fewer than six years in the same industry. Findings from a gender point of view indicate that male farmers have more farming experience than females. Nhemachena, Hassan and Chakwizira (2014:235) show that farmers with farming experience are in a better position to share information and knowledge especially with farmers who are not adapting. These farmers are regarded by Nellemann et al (2011) as adaptation agents of change.

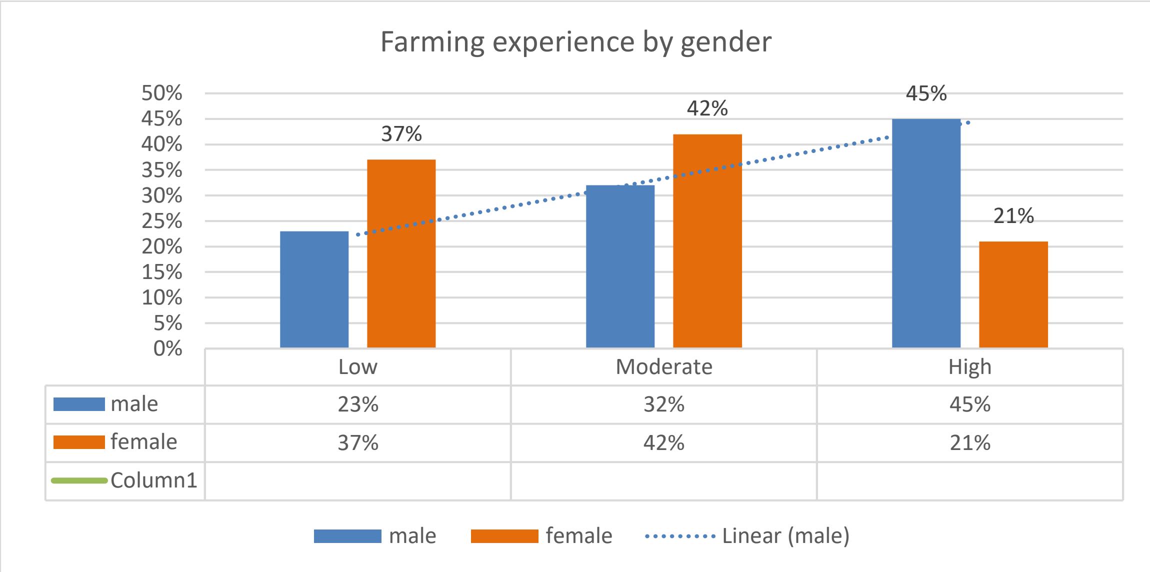


Figure 4.3: Percentage of farm experience by gender

Table 4.5: Distribution of participants according to their farm size

Item	F		%		Cumulative	Total %
No. of hectares	Female	Male	Female	Male		
>6 hectares	9	12	47	39	21	42%
6-10 hectares	8	15	42	48	44	46%
<10 hectares	2	4	11	13	50	12%
Total	fx=19	fx=31	100	100		100%

Table 4.5 shows that 21 farmers (42%) have less than six hectares of land. Twenty-three farmers (46%) have between six and ten hectares of land. Six farmers (12%) have more than ten hectares of land. From the qualitative findings, farmers with access to a reasonable amount of land have an opportunity to practice more than one activity such as crops and poultry production on the same land. These farmers can also practice crop rotation which requires a reasonable number of hectares of land. This implies that farm size has both a negative and a positive impact on adaptation. More

farmers with reasonable access to land were found to be practicing some of the no-cost adaptation strategies, such as crop rotation, than farmers with limited access to land. This stems from the fact that commercial farmers are dominated by fewer than 40 000 Whites who occupy 82 million hectares whilst 200 000 smallholder farmers, dominated by Black people, occupy 14 million hectares of agricultural land (DAFF 2012).

From the findings, other farmers under the area of the study are not utilising the whole of their allocated land due to financial constraints but were found to be practicing some of the adaptation strategies. These farmers plant between half a hectare to two hectares. Hence, findings from Deressa et al (2008:19) reveal that adaptation does not rely on the farm size, but the farm attributes trigger the precise climate change adaptation method.

Table 4.6: Themes which emerged from focus group discussions

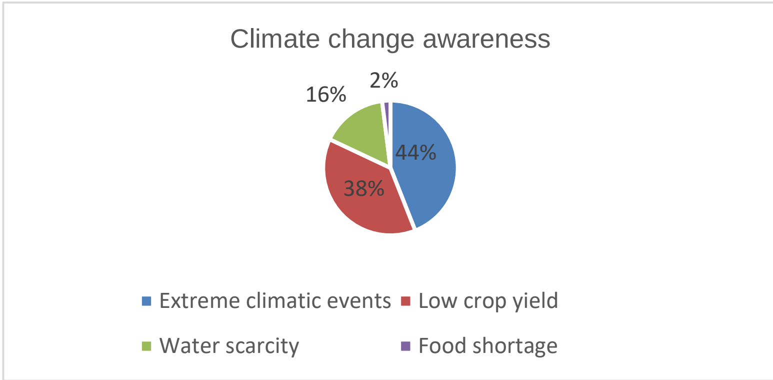
Research questions	Theme
What is your understanding of climate change?	Extreme climate events
What are impacts of agriculture in your area?	High socioeconomic loss
What adaptation strategies are you practicing in your area?	Limited adaptation strategies
What are the challenges are you facing when adapting to climate change?	Lack of financial and non-financial resources
How can adaptation at farm level be improved?	High agricultural investment

Table 4.6 presents extreme climate events, high socioeconomic loss, limited adaptation strategies, lack of financial resources, and high agricultural investment as findings from qualitative research. Qualitative and quantitative findings are jointly presented and interpreted below.

4.5 Extreme climate events

When farmers were asked about their experiences about climate change, most of their responses have been related to the manifestation of climate change in the form of high temperatures, changes in rainfall patterns, droughts, water shortage, floods, hail and frost in the area. The theme extreme climate events is a theme developed from these manifestations during discussions held with focus groups and key informants. This signifies that the extreme climatic events have been recently becoming common in the area, particularly affecting agricultural or farming sector. Extreme events occur when certain essential climatic variables reach extreme values, such as excessive amounts of precipitation (e.g., floods), severe winds (e.g., cyclones), and high temperatures (e.g., heat waves) that frequently cause damage.

Table 4.7: Qualitative and Quantitative Joint data display of farmers' experiences of climate change

Qualitative findings			**Quantitative findings**
Qualitative theme	Codes and	quotes by participants	
Extreme climatic events	Changes in rainfall patterns High temperature	*"You know, we farmers are suffering. To produce more, we are controlled by weather. Climate change affects all our plans. We even do not know what to do. The planting seasons have changed because the patterns of rainfall have changed also. Some years ago, it used to rain and water availability was not a problem. But now, not to mention farming, there is even a shortage of drinking water."* *"During summer, the temperature reaches 40 degrees which is too high for the crops to survive. In winter, the temperature reaches even 35 degrees during the day, and it is only cool during the night."*	 

The findings on Table 4.7 presented on joint display, concur that local farmers acknowledge the existence of climate change. Both quantitative and qualitative data show that farmers understand climate change in terms of how it has socially and economically affected them. From the combined data, the majority of farmers (44%), who are particularly vulnerable to climate change, have experienced extreme climate events like intense rain and high temperature resulting in flooding, droughts, hail, frost. Owing to these extreme events, farmers' decisions became negatively affected and their plans became ineffective. As a result, 38% of farmers claim to be at risk of low crop output, 6% experience water shortages, and 2% experience food scarcity.

This is because farmers have traditionally been acclimated to the rainy months, but they have recently begun to feel uncertain about them. For instance, during the months of April and May (2022) farmers experienced unexpected rains which delayed their planting season and eventually contributed to crop failure. Crop planting is usually seasonal, therefore missing it may have a significant impact on smallholder farmers' livelihoods.

4.5.1 Temperature and rainfall

Changes in rainfall patterns and high temperatures impacted farmers' planting seasons, since crops require a specific minimum and maximum temperature for growth and development. The findings show that the majority of crops failed to thrive at temperatures ranging from 35°C to 40°C resulting in poor harvest and low agricultural production. High temperatures cause greater evaporation in the area, which leads to heavy rains that damages crops. Both summer and winter day temperatures are similarly high, meaning that crops have a limited chance of surviving both the summer and the winter. Temperature can affect vegetable crops in many ways, including the timing and reliability of plant growth, flowering, fruit growth, and ripening (Plutland & Deuter 2011). Notably, high temperatures reduce the fruit set, size and quality of fruit resulting in low crop production.

FG1P5: "The pattern of rainfall has changed. Due to climate change, *it rains even in April and May months and these months were not associated with rain before.”*

FG2P3: “I am not able to take care of my family like I did before. It is difficult to be a man without money in the family.”

Some farmers purchased seedlings on time, however, owing to a missed planting date, the seedlings died before being planted due to unexpected rainfall. This was due to recent changes in rainfall patterns, which have altered crop calendars, causing traditional methods of forecasting planting seasons inadequate as farmers now rely on weather on a specific day to decide which crops to sow.

Climate events such as severe rainfall have a detrimental influence on smallholder farmers' production plans.
The findings further suggest that variability in temperature and rainfall in the area contributed to the development of pests and diseases that harmed farmers' crops. Pests and diseases caused farmers to use additional agricultural inputs, such as chemicals and fertilisers, which are expensive and unaffordable for many farmers, reducing agricultural productivity. Moreover, high agricultural inputs have a negative effect on food prices. As mentioned during focus group discussions, an example of this is the market price of tomatoes which increased to R40.00/kg in February 2021 due to low market supply caused by low agricultural production. This shows that high food costs may result in serious food shortages for many families if climate change is not dealt with immediately.

The agriculture industry relies on capital, which includes machinery, equipment, tools, and farm structures, to produce outputs (FAO 2023). With the regular occurrences of climate change, farming, as the only source of income, may not be enough to cover their needs, such as purchasing additional agricultural inputs, food purchasing and investing in farming to adapt to present climatic risks.

FG1P3: “To add on that, one litre of corogen cost R4000, we need *corogen for tomatoes."*

FG2P2: "Government fail to support us with chemicals, for example, they will never buy chemicals for tomatoes to farmers because they are expensive. What they do is to give us two bags of fertilisers. Is that a support?"

Farmers have little means of controlling diseases and pests that impact their crops due to overreliance on government. Farmers' overreliance on government may become maladaptive in the future because the government will need to increase the budget to cover many of them, which is already difficult.

This suggests that crops that can withstand the Ba-Phalaborwa climate should be explored to improve the livelihood of farmers as climatic variability harms farmers' agricultural yields prior to harvesting, leaving farmers exposed to no or low crop yields and food shortages. The primary cause of poor yields is variations in temperature and low soil moisture (Prasad & Chakravorty 2015:923). Furthermore, rising temperatures in Ba-Phalaborwa caused water shortages, making it more challenging for farmers to irrigate.

The findings are consistent with the IPCC's recent report (2023), which found that anthropogenic climate change has a negative influence on food and water security, human health, the economy, society, and nature, resulting in losses and damage. Contrary to Johnson et al.'s (2024) assertion that South African farmers have been able to adjust to seasonal variations in rainfall and temperature, the study's results show that farmers have historically become accustomed to rainy seasons, which may indicate a lack of scientific understanding of climate change.

It is critical to integrate both traditional and scientific information in order to improve adaptation planning and decision making. This may improve farmers' knowledge of sustainable agriculture while also increasing crop yields.

4.5.2 Farmers’ exposure to climate hazards

Hail, drought and floods are hazards experienced by farmers due to rising temperatures in the area leading to low agricultural production. These hazards impact the physical, natural and other assets of the farmers. For example, drought is a leading source of water scarcity and soil erosion, with severe consequences for the nations with limited resilience (FAO 2017).

> *Key informant: “Drought in South Africa is recurring; it started in 2016 and is still ongoing. Rainfall in South Africa is now less than 400mm per year.”*

> *“Farming is like gambling; you wake up today the weather is good and three weeks after planting there is drought.”*

> *FG2P5: “I have lost a hectare of patty pans and a hectare of baby marrows. The timing of hail heavy in 2018 was not good. I harvested once and the following morning, the area was left with nothing due to hail. I negotiated with workers on how to pay them because the source of income was destroyed by hail. There was no money to pay workers.”*

Farmers and key informants believe that hazards exist in Ba-Phalaborwa area. However, the majority of farmers identified floods and drought as the main hazards to which they are exposed. A few farmers identified hail and frost as threats, but they are infrequent when compared with drought and floods.

Hazards have a negative influence not just on agriculture, but also on farmer revenue, making producers unable to pay workers. Climate variability has resulted in recurring hazards, such as drought, in South Africa since 2016. The source of drought is the loss of evapotranspiration caused by the geographical region's high temperatures. South Africa has been receiving less rainfall annually due to drought, which has a detrimental influence on agriculture. Less rainfall indicates that farmers do not have enough water to irrigate their crops.

Recurrent droughts and other extreme climate events can cause a variety of problems for smallholder farmers, including low soil fertility, decreased productivity, livestock losses, restricted access to markets (FAO 2017), prevalence of pests and diseases, and a lack of water for irrigation and food shortage. Moreover, drought can lead to short- and medium-term water shortages, as well as significant heat stress on livestock and crops, which can reduce production (FAO 2021). As they are recurring, droughts have long-term repercussions, including land subsidence, seawater intrusion, reduced water flow, and ecosystem destruction, leading to severe famines, especially when accompanied with socioeconomic causes or violence (FAO 2021). Recurrent droughts deplete natural resources, such as rivers, making it difficult for farmers to cope with climatic shocks.

4.5.2.1 Low agricultural production and shortage of food

> *FG1P4: "With the high temperatures in this area, I incurred loss of inputs purchased, electricity to pump water, money to pay workers because of low production."*

> *FG1P6: "To add, my crops were attacked by diseases, and I lost all the money used to buy chemicals, seedlings, fertilisers. I sold nothing to the market and currently my family is suffering because of the loss. I am failing to buy food for my family."*

> *FG2P1: "Due to heavy rains experienced early this year (February 2021), the number of pests and diseases increased, and the loss was extremely high."*

Farmers suffered the effects of low crop production, loss of workers, loss of money and shortage of food which are the results of extreme climatic events like heavy rainfall and high temperatures occurring in the area. For example, the farmers were unable to purchase agricultural inputs, they lost production and they lost workers because workers' salaries come from production sales. FAO (2015) found that reduced income from agriculture prevents farmers from spending on education and food. The Parliament of South Africa (2017:117) agrees that low levels of employment in agriculture are intensified by climatic conditions and geographical locations. For this reason, qualitative data indicate that farmers have suffered significant socioeconomic losses.

> *FG1P5: "You cannot use title deed to secure credits. We women are the most vulnerable in this country. Bank do not consider us."*

> *FG2P1: "We borrow from family and friends."*

Due to a lack of financing, few farmers are able to safeguard themselves from climatic shocks as well as the predominance of pests and illnesses through borrowing. These climatic shocks are the cause of significant socioeconomic losses. Borrowing from family and friends is a short-term strategy used by farmers to recover from climate change shocks; however, this approach is not sustainable and is undermined by the frequent occurrence of hazards in the long term. Furthermore, during interviews with farmers, a lack of crop insurance was identified as a significant cause of socioeconomic loss due to the fact that the majority of farmers are either leasing or farming with permission to occupy, which limits their access to finance.

The findings show that, despite the fact that agricultural sector is essential to South Africa's economy since it supports both the country's social and economic demands, the effects of climate change keep destroying it. The findings further suggest that vulnerable individuals are likely to be at risk of hunger as more farmers, particularly smallholders who rely totally on government assistance, may struggle to feed the growing rural population in the future.

In 2020, 11.7% of the global population (920 million people) experienced severe food insecurity, and over three billion people struggled to afford nutritious food (FAO 2022b). As a result, climate change is expected to undermine the NDP's objectives of reducing poverty, inequality and unemployment, degrading communities' livelihoods. Given the rate at which climate change is occurring, farmers require access to resources, such as land and finance, in order to invest more in agriculture and feed the future population.

The findings correspond with findings by the South Africa Department of Agriculture Land Reform and Rural Development (2022) that heavy rains damaged and affected wheat harvesting times in the Free State Province whilst the 2021/22 growing season was affected by floods. Floods also affected vegetables and maize in Gauteng Province. Improving the adaptability of populations and systems in agricultural and food industries is crucial for managing future risk and uncertainty, reducing hazards and instability (FAO 2022b). Addressing vulnerabilities is crucial for improving food security, nutrition, and preventing consequences in the future (FAO 2017).

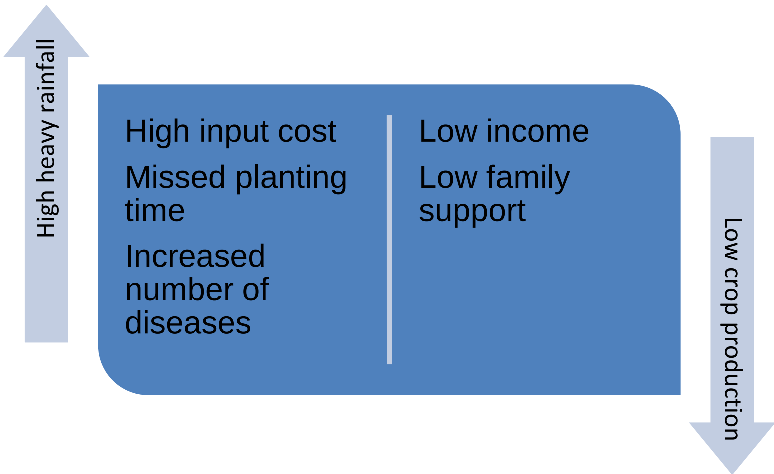


Figure 4.4: Heavy rainfall results in low crop production

4.5.2.2 Pests and diseases

Figure 4.4 demonstrates that, due to the extreme climate events in Ba-Phalaborwa, farmers are exposed to diseases and pests, such as fall armyworm, tuta absoluta, oriental fruit fly and blossom end rot, that are becoming prevalent and attacking and destroying the fields of farmers in the area. The statements and picture below support the results.

> *Key informants: "Exotic pests, such as fall armyworm, tuta absoluta, and oriental fruit fly, have never been seen in the country. Traps and chemicals are provided by the national department to control oriental fruit flies. Chemical measures are used to regulate the fall army*

worm. Tuta absoluta is a tomato leaf minor controlled by chemicals that is changed every week; it requires two chemicals to be manageable. Pests are not eradicated, but rather regulated."

Key informant: "We experience unknown new exotic pests from countries like Mozambique. For example, there was migration of grasshoppers in Selwane. Farmers reported this issue to us and, due to lack of transport, it took us three days to respond to their problem. When we arrived, their fields were destroyed, and the grasshoppers have already migrated. With these unknown exotic pests, we cannot talk about smart agriculture because pests require chemicals."

Figure 4.5: Picture of tomato crop affected by disease after heavy rainfall

The government's delay in delivering services to farmers in the area due to a lack of transportation as well as lack of knowledge about exotic pests increased farmers' losses. Although it was found during interviews that few extension officers received climate change training, the key informants also stated that Limpopo Province has two crop protection specialists that serve all local municipalities. This shows that extension officers lack sufficient knowledge of

exotic pests, necessitating the expertise of specialists – who are scarce not only in Ba-Phalaborwa but across the whole province.
According to key informants who are LDARD officials, excessive temperatures are the underlying cause of exotic unknown pests in Ba-Phalaborwa and South Africa as a whole. Key informants agree that, while these pests cannot be controlled, they can be managed by using chemicals, which is considered an unsustainable technique if used regularly. As a result, key informants suggested that implementing smart agriculture is impossible considering the influx of exotic pests into the country and the Ba-Phalaborwa area.

Contrary to the findings, it is critical that officials be exposed to knowledge about current climate impacts to help farmers increase their crop production. The findings correspond to FAO (2021) that globally, animal and plant pests and diseases are causing significant pressure on the human food chain. This suggests that agriculture's social and economic role has been undermined resulting in food shortages and lower income owing to decreased productivity.

4.6 Government's response to climatic shocks

> *Key informant: "Farmers [are] urged to apply for the relief grant; relief funds are not sufficient to cover all farmers as they are many. First come, first served, depending on when was application submitted and the severity after assessments done."*

> *Key informant: "Relief grant does not cover all loss. For examples, high and less loss, grant is standard."*

Key informants were asked how they deal with natural disasters or incidents like hail, drought and floods affecting farmers in the research area. Their responses were that there is a Comprehensive Agricultural Support Programme that helps farmers with shade nets, fertigation and others; nevertheless, they mentioned that one farmer will be assisted under GRASP this financial year (2022–2023). They added that the grants available to help farmers recover from climate shocks are insufficient and only cover few farmers. They also stated that even if farmers apply and receive the grant, it is unlikely to cover all of their losses as relief grant funding is standard regardless of the extent of loss farmers sustained.

This shows that, despite existing efforts, the Department of Agriculture and Rural Development's budget is insufficient to help farmers adapt to climate change. Owing to budget constraints faced by the department, farmers' reliance on government assistance may be unsustainable in the future. Farmers' vulnerability to climate change may worsen if the government fails to provide them with long-term support because they lack crop insurance. Most of the support is discussed in this chapter under the heading of “Farmers’ appropriate adaptation strategies to climatic hazards”.

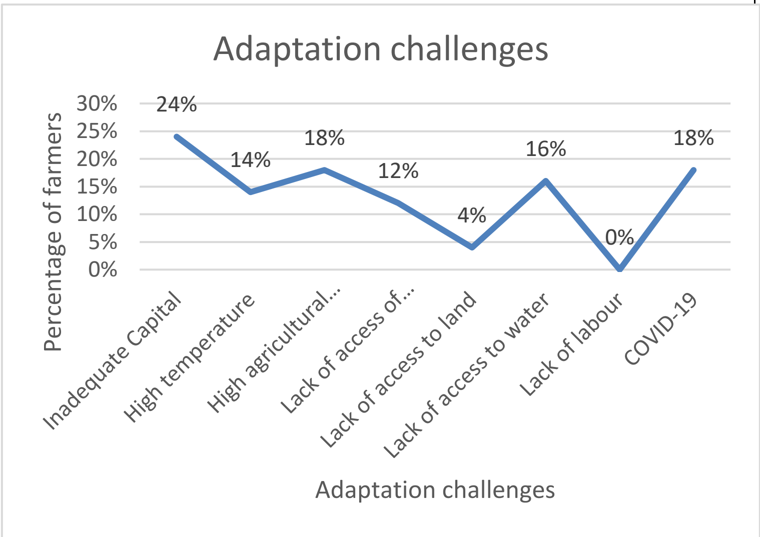
4.7 Lack of resources

For proper allocation of resources, it is important for decision makers to understand the problems farmers are faced with when adapting to climate change. This section presents and discusses factors hindering farmers from adapting to climate change.

The focus group discussion covered the question of the challenges encountered by farmers when adapting to climate change. The theme lack of resources is the finding from the qualitative data. Availability and accessibility financial, human, natural, social and physical resources are very critical in improving the livelihoods of the poor. Smallholder farmers’ inaccessibility of these resources can accelerate their vulnerability, increase poverty and reduce food security and also limit the adoption of adaptation strategies.

Table 4.8: Qualitative and Quantitative Joint Data display of challenges hampering smallholder to adapt to climate change

<table>
<tr><th colspan="2">Qualitative data</th><th></th><th>Qualitative data</th></tr>
<tr><th>Qualitative theme</th><th>Participants quotes</th><th>Qualitative findings</th><th>Quantitative findings</th></tr>
<tr><td>Lack of resources</td><td>“FG1P5: We farmers are poor, with the little money that I have, I managed to drill borehole, but water is not enough. I can pump water for two hours only per day. This is not enough to irrigate even one hectare per day.”

“Our institutions are failing us; can you call four bags of fertilisers a support or a voucher of fifty thousands a support.”</td><td>Codes developed from response from FG1P5 “little money” and response from FG2P4 “still struggling” indicate that, even though farmers are adapting, the lack of resources is a challenge. A lack of resources affects the production of farmers and slows the pace of adaption.</td><td>
</td></tr>
</table>

According to the findings from the joint presentation in Table 4.8, there are several obstacles preventing farmers from adapting to climate change. These include a lack of funding, a lack of institutional support, high agricultural input costs, high temperatures, a lack of climate information, a lack of land, a lack of access to water, and COVID-19. A lack of resources has a severe influence on agricultural productivity, making farmers more vulnerable to climatic hazards.

From 50 farmers, 12 farmers (24%) believed that adaptation to climate change had been affected by inadequate capital. High agricultural input costs were found to be another challenge that limits farmers' production and adaptation to climate change. Nine out of 50 (18%) farmers indicated that high agricultural input costs were a challenge. Eight out of 50 farmers (16%) reported a lack of access to water as their challenge. Fourteen percent (14%) and twelve percent (12%) mentioned high temperatures and a lack of access to climate information as the challenges they faced respectively. Twelve percent (18%) and four percent (4%) of farmers reported COVID-19 and a lack of access to land as challenges. COVID-19 emerged as a new challenge faced by farmers. These problems restrict farmers' ability to take advantage of existing adaptation methods in their location.

Both qualitative and quantitative findings concur that smallholder farmers in the study area had few resources, limiting their ability to adjust to climate change. Due to a lack of resources, farmers were exposed to extreme climate events that damaged and destroyed crop yields resulting in high socioeconomic loss. Farmers lost their income, resulting in food shortages and failure to care for their families. Farm workers lost their jobs and, as a result, these farmers' adaptation to climate change strategies was limited due to a shortage of resources.

4.7.1 Inadequate capital

A majority of farmers stated that a lack of money was the biggest problem hindering their production which reduces their income. This is because most farmers are poor as their means of survival is from agriculture which is vulnerable to climate change. As noted by FAO (2023), the agriculture industry relies on capital, which includes machinery, equipment, tools and farm structures, to produce outputs. Moreover, inadequate capital affects the majority of the respondents as farmers have less access to credit. This means that these farmers access credit at high interest rates (Parliament of South Africa 2018) and lenders run credit assessments which means that the poor are not able to repay loans due to their lack of collateral. Inadequate capital leads to poor adaptation by farmers and the reverse is just as true.

The study is in line with findings by Nhemachena et al (2014) that more access to financial resources, credit facilities, information and markets improves farmers' ability to adapt to climatic conditions (Nhemachena & Hassan 2007:20). This leads to better farming practices as farmers utilise available technologies such as irrigation systems, inputs such as fertilisers and improved crop varieties developed and designed to thrive in various climatic conditions (Nhemachena & Hassan 2007; Deressa et al 2008:11).

4.7.2 Limited extension services

Adequate support from institutions has a positive impact on the adoption of adaptation strategies by farmers. The findings show that farmers in Ba-Phalaborwa lack support from institutions as a result their slow adoption of adaptation strategies. The statements below from the same focus group discussions indicate challenges with access to extension services:

> *FG2P2: "Now as I speak, we were informed by our extension officer that their travelling kilometres has been cut to 450 kilometres per month. How are we supposed to be advised because the service centres do not have access to internet?"*
>
> *Key informants: "We are not doing justice to farmers; we do not have enough resources like transport."*
>
> *FG2P3: "The last time I saw an extension officer in my farm was in 2018. I phoned our extension officer several times requesting her to come and assist us as farmers. The reply that I got was that there*

are no cars, therefore I shouldn't expect her to come to the farm."

The results further show that extension officers and farmers agree that farmers receive minimal extension services in the area due to infrequent visit to projects by extension officers. Shortage of transport and internet access may be the reason for few visits by extension officers to farmers, leading to limited extension advise. According to the remark above, it could take up to a year for farmers to receive visits from extension staff.

When farmers were asked how they access information since they struggle to get service from extension officers, they said that they receive information from other farmers and through the internet. However, they indicated that access to data was another challenge they are facing.

When extension officers asked how early warning information is disseminated to farmers, key informants had differing views. According to many informants, they receive this information from the national department on a monthly and quarterly basis. However, many agree that shortage of vehicles create a communication barrier between themselves and farmers due to the fact that access to data is a challenge to many farmers. They, however, emphasise that information is disseminated during information days, farmer's days, and demonstrations, which may be delayed by the time it reaches farmers. Further than that, they claimed that the availability of officials with transportation access influences their planning, hindering service delivery and farmer adoption of adaption techniques. Few officials stated that farmers are rarely present, especially during harvesting season, but communicate via WhatsApp and phone calls.

The findings indicate that farmers in the area receive limited climate services due to the government's inadequate resources. Due to a lack of knowledge sharing, many farmers' productivity will decline as climate change worsens, resulting in food shortages and hunger affecting the majority of vulnerable people in the area.

Although the NPC (2012) reported that 17% of South Africa's population have internet access, the study's finding is different as internet access is a challenge for farmers and extension workers due to lack of resources. In contrast to Maponya and Mpandeli (2016), who discovered that farmers in Limpopo primarily obtained their climate information from radios, televisions, magazines, and newspapers, the results of this study show that farmers who have access to technology like cellphones are more likely to obtain information about climate change from extension officers through WhatsApp and the internet. Farmers without technology access suffer most since they rely on extension officers for information, which is currently difficult to obtain.

According to Unique-Kulima (2014), farmers, who access weather and climate information through the internet, are well resourced. This means that well-resourced farmers can gain climatic information and plan ahead of time before risks arise, as contrasted to farmers with little resources. Access to competent advising services is crucial for farmers to effectively execute climate-adaptive initiatives. The manner in which services are delivered and the assistance provided determine how accessible they are to disadvantaged populations (FAO 2024). With available and accessible climate information on a daily basis, farmers can plan properly (DAFF 2015). This is also backed up by the Human Impact Report (2009) that the damage by a cyclone in Bangladesh was minimal due to early warning disaster measures which were in place.

Climate change information should be available and accessible to farmers in Limpopo due to high climate variability (Mpandeli et al 2015:118). The sources of information and forms of communication vary between farmers, fellow farmers, farmers' facilitators and extension officers (Mdoda 2020). Unique-Kulima (2014) emphasises the important role played by extension officers in ensuring that weather and climate information is accessible and interpreted in a language which smallholder farmers understand due to their education background. Therefore, it is imperative to invest in personnel who will be able to communicate climate information in local languages (DAFF 2013).

COVID-19

> *"Any business is risky. It takes someone to have a heart to be a*

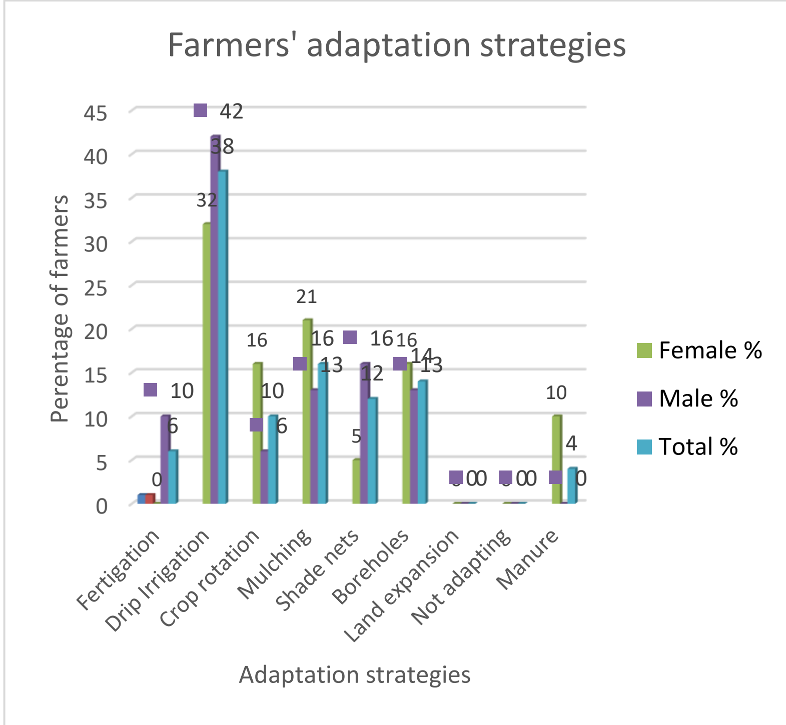
farmer. We are struggling because of climate change and now is COVID. During level 5 lockdown, I struggled with market. I sell most of my produce to hawkers on the farm. Some of the produce got rotten due to restriction of movement by government. I stopped some of my workers to come to work. I did not have money to pay them."

"Even family members and employees who helped us on the farm passed away."

COVID-19 added to the problems that farmers encounter in Ba-Phalaborwa. COVID-19 prevented farmers from selling their produce in the market owing to the government's level 5 lockdown. Furthermore, COVID-19 reduced farmers' incomes, resulting in job losses owing to failure to pay salaries. Prevalence of COVID-19 and negative impacts of climate change contributed significantly to the "high socioeconomic losses". COVID-19 killed many people who were working on their farms.

Table 4.9: Qualitative and quantitative data joint display of farmers adaptation strategies

Adaptation option	High/Low Priority	Activities	Responsible organisation	Outcome	Ranking
Shade nets	Moderate	-Farmers to submit request for assistance to government -Approval of request by government -Appointment of service provider to construct shade nets	Farmers and Government Departments	Improve crop protection	2
Drip irrigation	Moderate	-Purchase of drip pipes by farmers or through government support	Farmers and Government Departments	Improves water saving, crop production	2
Agricultural inputs (Seed cultivars, fertilisers, chemicals)	High	-Purchase of agricultural inputs	Farmers and Government Departments	Improves yield	1



Boreholes	High	-Drilling of new boreholes -Increase depth of existing boreholes	Farmers and Government Departments	Increases access to water for irrigation	1
Agricultural Equipment	Low	-Purchase tractors, fertigation, implements etc.	Farmers and Government Departments	Increase savings	3
Weather and climate information	High	-Disseminate climate information	Government	Improves access to information	1
Land	High	-Allocate land to farmers	Government	Increase diversification and crop rotation	1
Manure	High	Application of manure	Farmers	Reduce input costs	1
Mulching	High	Employment of more labour	Farmers	Improve employment	
Diversification	High	Mix of enterprises (tomatoes and broilers)	Farmers	Increase income	1

To discover whether or not farmers adapt to climate change, questions concerning their available alternatives for adaptation were asked. This section shows and discusses the findings of effective adaptation techniques for Ba-Phalaborwa farmers. Both qualitative and quantitative findings reveal that most farmers in Ba-Phalaborwa made limited efforts to cope with and adapt to the negative effects of climate change. Some socioeconomic factors such as gender, income, and education, prevented farmers from accessing these strategies. For example, gender findings of this study revealed that access and control of resources differs between males and females. This findings suggests that farmers with limited access to and control over resources adopt fewer strategies as because of their poor adaptive capacity, in contrast to farmers with access to and control over resources who adopt several strategies as a result of their high adaptive capacity.

4.8 Farmers' appropriate adaptation strategies to climatic hazards

Farmers in Ba-Phalaborwa identified shade-nets, drip irrigation, agricultural inputs, boreholes, agricultural equipment, weather and climatic information, land, manure, mulching, diversification, crop rotation, and fertigation as effective strategies for dealing with and adapting to climate change impacts. In addition to the findings, strategies with a 'high' priority reflect the urgency of the strategy to increase agricultural productivity, as well as the steps taken by farmers and the government to achieve these strategies. Prioritising strategies is crucial as it enabled farmers to discover strategies to implement on their own without support from other organisations.

The quantitative findings from table 4.9 show that 38% of respondents, or the majority, use drip irrigation systems as a climate adaptation strategy because the area experiences high temperatures, which have a negative impact on water availability and accessibility. Another reason is that farmers received government assistance in the form of drip pipes, hence the method has been adopted by many farmers.

Eight farmers (16%) use mulching as one of their adaptation strategies. Seven out of 50 farmers (14%) agreed that boreholes are an adaptation strategy to address the challenge of water shortage due high temperatures in the area. This is followed by twelve percent (12%) of respondents who practice shade nets as a way of adapting to climate change. Ten percent (10%) of farmers practice crop rotation as a strategy of adapting to impacts of climate change while six percent (6%) use fertigation. The least strategy practiced by farmers is application of manure at four percent (4%).

4.8.1 Shadenets

The qualitative and quantitative data indicate that shade-nets are one of the acceptable ways farmers utilise to adapt to harsh weather occurrences in the area. This method is used by just 6% of farmers in the area, indicating a low adoption rate. The slow adoption of this method may be due to the fact that it is affordable to farmers with a high adaptability. Hence, the findings demonstrate that farmers who implemented this technique received government support. Moreover, during the discussions, extension officers stated that some farmers received shade-net support but did not use it. *When asked about the reasons why these farmers are not using the shade-net,* they responded that there is a flawed criteria utilised by the government to select farmers, which resulted in farmers being unable to connect electricity for shade-net operation.

Shade-nets have several advantages, including the ability to produce high-value crops with high yields and market access. Farmers who utilise shade nets are more likely to make a profit than those who do not. This indicates that shade nets may boost farmer production, contributing to increased income and reducing crop exposure to hazards.

> *FG2P3: "With the shade nets received from government, I am able to plant high value crops, like pepper, with good quality and sell to market. The yield is also high, maybe is because my borehole has high volume of water."*

Figure 4.6: Picture of shade net

Shade nets as shown on Figure 4.6 are important to farmers because they increase quality and agricultural yields and prolong harvesting days when compared to planting in open fields. For example, one farmer indicated during project visit that, “*I harvest my peppers for six months inside the shade net*”. The strategy also created a market opportunity to few farmers. Despite the strategy's slow adoption, key informants stated that it reduced sunburn from the high temperatures, enhanced farmers' agricultural output, and increased farmers income. The method also protects crops from adverse weather conditions such as hail and frost. This study concurs with the findings of Tinyane, Lemmer, and Sivakumar (2018), who discovered that shade netting prevents the detrimental effects of climatic extremes such as sunlight, wind, and hail. This is important as the area is exposed to hail, frost and drought that can destroy crops easily.

4.8.2 Water sources for irrigation purposes

The researcher's field tour revealed rivers, canals and boreholes as water sources utilised by farmers to irrigate their crops. These sources are dry due to the area's severe temperatures and drought. As a result, water scarcity had a significant influence on agricultural growth and productivity, forcing farmers to utilise excavation to extract water from rivers. According to DEA (2017a), the explanation for the water deficit is a decrease in yearly rainfall in Limpopo between 1921 and 2015.

During focus group discussions, drip irrigation has been discovered as one of the techniques farmers utilise to irrigate their crops. The method outperformed other strategies because it is adopted by a large number of farmers (38%), due to the government's extensive support to farmers in that area. Since the area is dry owing to high temperatures, farmers are exposed to climatic risks such as drought, which causes water shortages. The drip method assisted farmers in surviving these conditions by saving water while improving productivity. These findings are backed by the participant quotations shown below.

> *FG2P1: "The rivers are no longer flowing like previous years as told by father. Government needs to intervene because I drilled a borehole with a depth of 60m without success. Support, in terms of drilling more metres up to one hundred and twenty might be helpful."*

> *FG1P5: "We farmers are poor, with the little money that I have, I managed to drill borehole, but water is not enough. I can pump water for two hours only per day. This is not enough to irrigate even one hectare per day."*

When asked what advice they give farmers on irrigation in light of water scarcity, key informants responded that farmers are advised to irrigate at night to conserve water because drip irrigation distributes water directly to crops, lowering water demand and evaporation losses particularly in areas prone to climate change impacts such as seasonal droughts. Whilst many farmers embrace this method, others continue to experience the repercussions of climate change because they lack the capacity to adapt and are unable to acquire water due to dry water sources. This shows that the unpredictable nature of rainfall patterns caused by climate change, along with high temperatures, expose farmers to water scarcity, making them more sensitive and less able to adapt to specific climate change strategies.

Figure 4.7: Picture of dry borehole

According to the data, boreholes with little or no water are the most reliable supply of water for farmers. DAFF (2013) claims that the cause of the lack or scarcity of water is the frequent occurrence of high temperatures and drought which has a serious impact on water availability. The findings further indicated that crop yields can suffer if farmers fail to adapt to this strategy. Although water is a requirement for optimum growth and yield, the sustainability of this strategy is not clear since research findings revealed that a limited volume of water is discharged from the borehole. For that reason, Mpandeli et al (2012) found that there is not enough groundwater and surface water. Boreholes are thus a short-term adaptation option for farmers to adopt during a water crisis, but the method may increase farmers' vulnerability to water shortages by exacerbating the water problem in the long run owing to extreme temperatures.

The results are consistent with those of Chikozho, Managa and Dabata (2020), who found that sixty percent (60%) of farmers in Sekhukhune District in Limpopo Province had challenges of access to water. The proportion was more than that of farmers with access to water. Farmers who had water challenges were involved in other livelihood activities such as livestock farming and farming on arable land. For farmers to implement sustainable irrigation in a world where water is becoming more scarce, climate adaptation methods include lowering irrigation water demand, boosting soil moisture, along with improving water productivity (Rosa 2022). However, the researcher contends that drilling boreholes may increase the cost of acquiring water in the near future. This area requires additional investigation in order to provide accurate advice to the government.

4.8.3 Agricultural inputs, agricultural equipment and manure

> *FG2P4: "Government supported at least some of us with drip pipes. We are able to save water during irrigation since water goes directly to the root of the crop. But still struggling to buy agricultural inputs because of high prices."*

> *FG1P3: "With the shade nets received from government, I am able to plant high value crops, like pepper, with good quality and sell to market. The yield is also high, maybe is because my borehole has high volume of water."*

> *FG1P1: "Fertilisers and chemicals are expensive. I end up using one bag of fertiliser while I am aware that the area planted need four bags of fertilisers. Fertilisers and chemicals are expensive, and we cannot afford and this affect production."*

> *FG2P3: "They give you KAN when you asked for potassium nitrate. They give you seedlings that need potassium nitrate. What to do with something you did not ask? Actually, government does not respond to our needs."*

According to the findings, farmers believe that using agricultural inputs such as tractors, seedlings, fertilisers, and chemicals increases agricultural productivity. The majority of these agricultural inputs were gained by farmers through government support because farming in the area thrives to withstand climatic challenges, leading farmers to have little income, preventing them to invest in some agricultural inputs.

This highlight that agricultural inputs are crucial for increasing farmers' agricultural productivity and profit. They also claim their lack of capacity to acquire enough agricultural inputs owing to increased prices leading to low agricultural productivity. As inputs are expensive, several farmers used fewer bags of fertilisers from government, resulting in a significant crop loss. This implies insufficient government support for farmers, which hinders their ability to respond to extreme weather events.

The war between Russia and Ukraine resulted in expensive agricultural inputs, as the Russian Federation is a major fertiliser exporting country (FAO et al 2023). The conflict has significantly increased global food costs as these two countries are the major producers of agricultural commodities. Food commodity prices had been gradually rising before the war, but the additional uncertainty caused by the conflict caused them to continue to rise (FAO et al 2023). Agricultural production was affected by droughts and floods, as well as rising fertiliser prices globally. Moreover, 4% of farmers use manure instead of fertiliser in order to decrease the high cost of agricultural inputs.

4.8.4 Diversification

Farmers were compelled by the high temperatures to cultivate native crops that are able to tolerate the local temperature. Growers produce indigenous crops such as okra, maize, groundnuts, and Bambara ground nuts. Diversification of the business, such as raising broilers and vegetables, has been regarded as a viable approach that farmers may use. This is because if one commodity does not perform well, the other can recuperate the income lost by the other.

> *FG2P6: "I plough groundnuts and bambara groundnuts for in case where I can incur loss from vegetable production. Previously, I made good money."*

> *FG2P5: "Even maize and okra survive to different climatic conditions. It is an option in this area."*

> *FG1P4: "I think the option of having different enterprises can assist us to recover from the shocks. For example, I am currently selling tomatoes and, at the same time, I am involved in broiler production. The income of one enterprise assists in the challenges encountered*

from the other enterprise."

Key informants: "We used to have original seeds, but new technologies offered by companies such as Monsanto, Beyer, and others, introduce drought-tolerant seeds which has impact on our health since the seeds are modified. Farmers are unable to use seeds from past cycles as a result of these new technology. Why can't we return to our indigenous knowledge? Our great-grandmothers used to store seeds in silos, which were preserved to be used in the next season. Recently, farmers purchase seeds every season from dealers, which is expensive."

Farmers and key informants agree to grow indigenous crops. However, key informants stated that the latest method for developing drought-tolerant seeds necessitates farmers purchasing seeds from suppliers each season, which is expensive. Furthermore, the key informants show dissatisfaction with these seeds as their modification poses a risk to human health. As a result, they advised that some traditional farming methods should be revisited in order to save farmers money.

4.9 Agricultural investment and its importance

When farmers were asked about what motivates them to adapt to climate change and how can farm level adaptation be improved? Below are some of their responses.

FG1P3: "We have received enough training as farmers. As I am speaking, I have collected several certificates. Any institution is offering training to us. Why can't they trust us by giving us money?"

FG1P5: "You cannot use title deed to secure credits even if you have it. We women are the most vulnerable in this country. Bank do not consider us."

FG2P1: "We borrow from family and friends."

The responses show that farmers cannot invest in agriculture without support from institutions such as banks and government, but banks are not supporting farmers, especially women. Even though, investment in agriculture requires farmers' access to capital, however, lack of land ownership is regarded as an obstacle for farmers to obtain credit.

The FAO (2018) explains that investing in agriculture is a key component to improving agricultural production and it also has the potential to address and reduce poverty, improve incomes of households, provide food that is affordable and further contribute to the economic growth and environmental sustainability. In South Africa, investment is regarded as critical by the CDE (2018) as it improves levels of agricultural production and ensures that the country has access to affordable food. Notwithstanding the fact that South Africa's investment in agriculture fell from thirty percent (30%) of GDP to sixteen percent (16%) between 1980 and 2000, the NPC (2012) notes that infrastructure is necessary for development as it improves the lives and incomes of the citizens (NPC 2012).

The European Environmental Agency (2019:21) perceives that some benefits of the agricultural sector emerge from prioritising investment in technologies, such as drip irrigation systems and wastewater use, which are water efficient irrigation methods. Investing in agriculture assists farmers to achieve higher incomes and better yields in the future. Regardless of that, farmers have insufficient capital to pay their workers as they have to purchase agricultural inputs and other farming equipment (Owusu et al 2014).

The DEA (2017) identified and prioritised the Agriculture, Food Systems and Food Security Flagship Programme as amongst the climate change investment areas in South Africa. However, Kiker (2000) observes that access to technologies such as drought resistance cultivars and irrigation technologies can be hampered by a lack of financial resources. The CDE (2018) believe that the government needs to direct support as per the needs of smallholder farmers as they are undercapitalised and do not have the capacity to invest.

Examples of agricultural investments include the purchase or building of real property, such as residential or commercial land and/or real estate; and the purchase of machinery, equipment and transport for commercial purposes (FAO 2018). Farmers in the area of the study also identified the construction of water storage facilities, such as dams and reservoirs, and the breeding of new cultivars that are drought tolerant as some of their priorities for investment.

Shade nets and investment in irrigation systems were also identified as agricultural investments by some farmers. Shade nets protect agricultural crops, particularly horticulture crops, from the sun, pests and from extreme weather events such as hail, frost and wind (Muscalu, Tudora, Cota & Gyorgy 2020:3). Considering the role played by shade nets in farming, the study discovered that farmers were practicing intercropping to reduce pests and diseases and to improve the structure of the soil. Findings by de la Peña (2007) reveal that shade shelters prevent crop damage by rain or sunlight. Notwithstanding the fact that smallholder farmers lack capital to invest in agriculture, the DALRRD (2020) promotes the usage of drip irrigation as it saves a lot of water.

> *FG1P2: "Department of Agriculture and Rural Development supported me with a shade net. My crop quality and production has improved since using the shade net. The shape, the size and the production are much better as compared to planting in an open space before."*

The statement above is evidence that agricultural investment improves agricultural production, which results in an increase in farmers' income. Vermeulen and Cotula (2010) support the above statement and add that increasing investment may improve both on the micro level by creating opportunities to raise living standards in local areas and on the macro level through contribution to GDP. However, financial institutions are critical role players in the provision of finance for growth and for improving adoption of new technologies (FAO 2018) and to ensure that investment in agriculture is provided to farmers who could not access support from the government.

Besides the fact that financial institutions are far from rural areas and are not accessible for agricultural producers as indicated by Owusu et al (2014), they charge smallholder farmers high interest rates on credit which makes them continuously poor (Parliament of South Africa 2018). This means that government needs to ensure that the barrier of inaccessibility is addressed. It is envisaged that a lack of investment in South African agriculture could result in decreasing the values of agricultural export by 40 percent and jobs from the high value export crops by 30 percent (BFAP 2018). Exporting crops brings foreign currency and government revenue.

Besides agricultural investment several factors motivate farmers to adapt to climate change. They include: better education; access to food; fear of threats such as drought, floods, frost and high temperatures; borrowing from family and friends; heavy rainfall. and institutional support.

4.10 Chapter summary

The chapter presented and discussed the profile of farmers in relation to climate change. The experiences of farmers about climate change which included various hazards and how they affected their production have been discussed in this chapter. Their challenges and response to these impacts were presented and discussed using joint display for better interpretation. The last section covered is the chapter summary.

The next chapter will discuss the summary of key findings, how the objectives of the study have been achieved, the contributions of this study, conclusion and recommendations.

CHAPTER 5: SYNTHESIS OF MAJOR FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of findings, discusses how the study's objectives and goals are attained. This is followed by study contributions, conclusions, and recommendations from study’s findings.

5.2 Discussion of summary of findings

This study aimed to explore the experiences of climate change and to analyse the techniques implemented by smallholder to adapt to extreme climate events. The results indicate that smallholder have experienced climate change and they are currently using measures to adapt to it. Further findings indicate that human activities are the reason of the extreme climatic events. Key findings are discussed using climate change-related themes.

5.2.1 Smallholder farmers’ vulnerability to climate change

The findings of this study show that socioeconomic factors such as gender, age, education, farm size, and income influence smallholder farmers' vulnerability to climate change by limiting their adaptive capacity. Understanding how these factors relate to climate change may assist decision makers consider them when developing or reviewing policies. Furthermore, decision makers may be able to integrate these features into policy in order to direct resources to vulnerable groups, as indicated by the National Adaptation Strategy in Chapter 2 of this research.

In terms of gender, more male farmers were discovered to be involved in farming than females, making females more exposed to climatic impacts than males, resulting in less adoption of adaptive techniques. The unequal distribution of wealth has been caused by socio-cultural and political power differences between men and women. Gender disparities in climate change and resource distribution require additional investigation. Farmers with education were found to be more able to adjust to climate change than those without education.

The age factor also revealed that young people have a better chance of being exposed to technology and accessing climate information than older people. With the increasing demand for technology introduced as a result of climate change, it is critical to have policies that integrate and deploy technologies as needed by farmers in order to improve support for adaptation measures.

Few elderly farmers found to have climate change knowledge due to their experiences in years involved in farming. Youth have no interest in farming due to being employed by non-agricultural sectors. The result is important because in the next coming year, projections showing that temperature will continue to increase, youth will be able to survive climate shocks as their income is from off-farm activities. However, the rising population is likely to experience food shortages as future producers are involved in other activities.

Farmers who have longer farming experience were shown to have more knowledge about climate change than farmers with fewer years. These farmers have been exposed to a variety of threats and have developed techniques to deal with them.

Many farmers' primary source of income is farming, making them less adaptable to the current effects of climate change. Findings revealed participating in non-agricultural enterprises as additional methods for farmers to diversify their income. The technique may boost farmers' revenue, allowing them to engage in adaptation strategies such as paying agricultural inputs and infrastructure like boreholes, fertigation, and shadenets.

5.2.2 Smallholder farmers' experiences of climate change, causes and impacts

The findings reveal extreme climate conditions, such as heavy rainfall patterns, droughts, floods, frost, hail, heat stress, tornadoes, hurricanes, cyclones as natural and human-caused hazards impacting significantly on livelihood of farmers. These hazards have been found to be exacerbating the challenges smallholder farmers are encountering. Latest report by IPCC (2023) show that unusual high intense heat waves have been experienced in some parts of America, Europe, Asia and Africa.

These extreme climate events have caused smallholder farmers to lose their livelihoods and agricultural investment. Some high socioeconomic losses that occurred due to these hazards include amongst others land loss, water loss, income loss, job loss, food loss, loss of education, livestock loss, and crop loss. The study found that burning residues by farmers may cause veldfires if managed inappropriately which in turn affects their livelihood sources. Furthermore, deforestation caused by tree cutting for agricultural development and shelter provision could accelerate the occurrence of hazards.

Anthropogenic climate change has been found to be contributing significantly to these losses. The findings are consistent with the IPCC's (2023) report that anthropogenic climate change has an impact on food, water, human health, the economy, society, and the environment, resulting in losses and harm.

The findings are further consistent with those of DEA (2017c), which found that wildfires devastated grazing land, livestock, homesteads, and water infrastructure, prompting the local municipality in KwaZulu Natal and Free State province to declare a state of disaster, and costing the state a lot of money.

As a result, the frequency of hazards increases, exposing not only farmers but the entire society to losses. This suggests that burning wastes and cutting trees for land expansion are part of a maladaptive approach since they may cause the government to spend a significant amount of money to cover future losses.

According to the findings, farmers are among the drivers of climate impacts since food systems contribute significantly to GHG emissions, which raise temperatures and increase the likelihood of risks. Agriculture, through livestock and crop production, is a prominent source of GHG emissions. Land is crucial for gaining wealth, power, and influence in rural different cultures, serving as the foundation of agricultural output (FAO 2022b). It should also be noted that agriculture's contribution to climate change is induced by other reasons such as land degradation in order to expand land to provide enough food owing to population growth. Hence mineral fertilisers, for example, have been overused and poorly managed, resulting in various amounts of groundwater pollution in almost most developing countries. The contamination has consequences for agricultural and natural systems downstream, as well as high expenditures for purifying drinking water (FAO 2011).

Mining and deforestation have also been identified as non-agricultural contributors to climate change. Several countries rely heavily on the mining industry for economic growth. Deforestation has been identified as a survival strategy adopted by individuals to deal with climate shocks caused by climate change. The technique also generates cash through the sale of wood. This suggests that, while climate change is an increasing issue worldwide, some vulnerable populations require climate change awareness campaigns.

Given that South Africa is a water-scarce country, crops that are heat and drought tolerant and require less water should be explored in order to save the country's expanding population, as forecasted by Stats SA 2023. Furthermore, planting indigenous drought-tolerant vegetables such as cowpeas, curcubita, and C Pepo, as discovered by this study, may prevent the vulnerable group from food shortage, which is one of the issues that farmers face. According to Agri SA (2016), this may assist the government in ceasing the import of staple foods. The rate at which the country's population and climate change are growing suggests that the country may become food insecure in the future.

Farmers can generate sustainable energy from agricultural wastes such as manure and residues rather than leading to veldfires through residue burning.

Manure management can boost soil fertility as it is stored directly on the land (Wang et al 2016). On-farm electricity generation may decrease electricity expenses and protect farmers from energy inflation (Beckman & Xiarchos 2012). This implies that farmers may practice waste management for the protection of environment.

The findings showed that high temperatures and heavy rainfall contribute negatively to planting decisions of farmers. For example, these climatic events prolong the growing season and affect crop development stages. Some farmers miss planting times whilst other farmers fail to harvest their crops on time resulting in serious losses. Water shortages, due to drought, are a problem as crops need water to grow. Heavy rainfall caused the disruption of water intake by plants and, as a result, tomato plants experienced crop diseases, such as calcium deficiency, which require expensive chemicals that many smallholder farmers are unable to afford.

The most vulnerable group to the impacts of climate change are females due to the unfair distribution of government support by male committee members who are in charge of the distribution of resources. This calls for further research to examine the impacts of climate in terms of gender as there is a need to understand and respond to the specific risks and vulnerabilities faced by men and women, and to distribute resources accordingly to address the disproportional impacts of climate change.

5.2.3 Adaptation constrains for smallholder farmers

The findings revealed that inadequate financing, high temperatures, high agricultural input costs, lack of access to climate information, lack of access to land, high food prices, pests and diseases, lack of access to water, and an outbreak of COVID-19 are among the issues limiting farmers' ability to adapt to climate change. The main causes of these constraints were extreme climate events such as high temperatures, heavy rainfall, frost and hail which were found to be perpetuated by a lack of resources. These problems have a negative influence on agricultural production, which lowers farmer incomes. As a result, more farmers are exposed to hazards leading to a decline in agricultural investment and a slow and limited adoption of climate change adaptation techniques.

Extension officers, for example, are unable to provide effective services to smallholder farmers due to a lack of resources such as internet access, lack of knowledge, and transportation due to institutional budget constraints. When grasshoppers infested and damaged farmers' fields, they received little assistance. Farmers failed to receive sufficient technical guidance from extension officers, which exacerbated their farming conditions and lowered their standard of living because their livelihood was severely harmed. Land is also a challenge because of land disputes with traditional authorities which led to the eviction of some farmers that prevented them from practicing adaptation strategies such as crop rotation.

From these findings, institutional support such as banks, extension services, water organisations, government departments, and others, emerged as being critical to enhance farm level adaptation to climate change. Based on that, it is recommended that climate change stakeholders need to work jointly through the contribution of both human and financial resources to enhance the adoption of climate change strategies by smallholder farmers.

Working together is crucial because it will bring together multiple stakeholders who will commit their resources and ensure that these resources are allocated to improve smallholder farmers' adaptations to climate change. Working together can also improve agricultural investment, which needs diverse stakeholders to pool their resources in order to increase crop yields. Two government departments are devoted to assisting smallholder farmers in the area of the study but these will be minimised if both the public and private sectors would share responsibility for responding to the needs of smallholder farmers.

5.2.4 Coping and appropriate adaptation strategies of smallholder farmers

The study's findings revealed that smallholder farmers identified solutions to handle the effects of climate change, despite the hurdles they faced. Income diversification through non-agricultural enterprises has been shown to increase farmer income and help farmers reduce the barrier of limited resources. Due to a lack of resources, strategies implemented include the use of drip pipes, the application of agricultural inputs (seeds, seedlings, fertilisers, and pesticides), shade-nets, fertigation, borehole drilling, the application of manure,

diversification, crop rotation, mulching, and the planting of bambara groundnuts, groundnuts and okra. Farmers and key informants strongly suggested indigenous crops as an adaptation option.
The data demonstrated that farmers received little government support; nonetheless, the majority of smallholder farmers' strategies are the result of government support.

Women were shown to have less access to resources as a result of gender power dynamics. The findings demonstrate that, given the projections of rising temperatures, certain strategies, such as borehole drilling, are believed to be maladaptive, possibly costing the government lots of money in the future due to a reduced groundwater level.

Strategies such as drip irrigation help farmers to save water. Some farmers benefited from shade-nets as their crop quality, size and quantity had increased whilst agricultural inputs improved their crop yields. Fertigation ensured that crops receive the same quantity of fertilisers. Smallholder farmers identified their own low-cost strategies, such as applying manure to reduce fertiliser costs while improving soil quality and yield, mulching to retain soil moisture, and planting drought-tolerant crops such as okra, bambara groundnuts, and other crops suitable for the climate of that region.

The findings indicate that the government's support to farmers in the study area is insufficient. Nonetheless, the government, through DALRRD and LDARD, has invested in agricultural infrastructure like as fertigation, shadenets, and irrigation systems through various initiatives to help farmers cope with the consequences of climate change. Furthermore, to improve production in agriculture, the government provides further support to farmers in the form of agricultural inputs such as pesticides, seeds, seedlings, fertiliser, tractors, and equipment.

Furthermore, farmers were given vouchers during the COVID outbreak to compensate for losses encountered during lockdown. The government also ensures that farmers receive support when they are affected by natural disasters.

It is apparent that smallholder farmers cannot adjust to climate change impacts on their own; thus, interventions by institutions, including government, are required for successful adaptation. The findings discovered that certain strategies, such as shade nets, were underutilised as a result of choosing farmers without considering their capacity in terms of finance to utilise shade nets. The criteria used by LDARD to choose which farmers to support were found to be incorrect. The other reason for underutilisation was resistance to change.

5.2.5 Adaptation improvement

Agricultural investment has been identified as a vital component for improving farmers' ability to adapt to climate change and increasing smallholder farmer productivity. To achieve this, the appropriate actors must collaborate by deploying both their human and financial resources. The findings revealed that few smallholder farmers have invested in drip pipes, fertigation, machinery, and shade nets because of a lack of adaptive capacity. This also hampers the ability of smallholder farmers to practice several adaptation strategies. This kind of investment requires access to funds which seems to be an obstacle for smallholder farmers.

The smallholder farmers believe that, with agricultural infrastructure investment, they can produce higher quality crops at high quantities. Agricultural investment may increase farmers' revenue, allowing them to choose and implement a variety of adaptation tactics.

During focus group discussions, the construction of dams and reservoirs, and investing in irrigation systems were highlighted as crucial agricultural investments that required financial resources to tackle the issue of water scarcity and increase water saving. A policy gap that limits government investment in dams is a lack of resources (DWAF 1997). The researcher argues that this investment is a prerequisite as it serves as a storage of water for irrigation purposes, and it can assist in protecting and improving the yields of farmers during high temperatures where different hazards are recently common. Literature also demonstrated that smallholder farmers do not invest in agriculture due to resource scarcity. Farmers with limited resources use fewer techniques and are more vulnerable to the consequences of climate change than farmers with more alternatives for adapting to climate change. The other area of investment found to be crucial was investing in breeding cultivars that can survive the harsh extreme climate conditions to maintain food availability and reduce poverty in rural areas.

The study found that producing enough food needs investment in water as crops require water for optimum growth. This requires dams and reservoirs to store water for irrigation purposes. Droughts also need cultivars that are drought tolerant to survive in extreme temperatures and to increase crop yields. Due to low self-efficacy, smallholder farmers are slowly adapting to climate change effects.

5.3 Achieving purpose and objectives of the study

The results of the study helped to achieve the objectives and purpose of the research. The purpose of this study was to understand climate change concept from the views of smallholder farmers of Limpopo Province, and to analyse the strategies they employ to protect and increase their agricultural production. This section discusses how the objectives outlined in Chapter 1 were achieved.

Objective 1: To ascertain smallholder farmers understanding of climate change and its causes

This objective was achieved from participants statements under theme 1 (extreme climate events) in Chapter 4, from codes in Figure 3.6 of Chapter 3, Figure 3.9, and joint data display Table 4.7 in Chapter 4 demonstrated that smallholder farmers have experienced climate change as the codes elicited from their statements included: high temperatures, heavy rainfall, droughts, floods, missing planting data, and destroyed crop yields. For example, joint data display in Table 4.7 supported the understanding of smallholder farmers of climate change since 44% and 38% of the respondents indicated extreme climate events and low crop production as indicators of climate change respectively. The main causes of climate change as attributed to human activity were covered in detail in Chapter 2. For instance, deforestation and water depletion due to land degradation impact crop quality and quantity, ultimately resulting in food insecurity.

Objective 2: To determine the extent of the effects of climate change on agriculture

This objective was achieved in Chapter 2. Table 2.3 discussed the direct and indirect impacts of climate change with a focus on water, agriculture, biodiversity and social factors. In addition, the results in Chapter 4, Figure 3.7, Figure 3.9, Figure 4.5, Figure 4.7, and the summary of findings in Chapter 5 helped to achieve this objective. Table 2.3 revealed that agricultural production was reduced, and crop irrigation requirement increased due to high temperatures. For example, the study found that climate change has a negative impact on smallholder farmer families, preventing them from providing food or paying for their children's education, reducing their income and increasing vulnerability and poverty.

Exotic pests and diseases that destroyed fields in the study area were another example. People's livelihoods were jeopardised when some farmers were not work owing to low productivity.

Objective 3: To analyse the strategies practiced by smallholder farmers when adapting to climate change

This objective was achieved in Chapter 2, Chapter 4, Chapter 5, Matrix Table 3.2, Figure 3.9, Figure 4.6 (picture of shadenet), joint display Table 4.9 discussed in detail the achievement of this objective. Fewer strategies were found to be adopted and implemented by smallholder farmers who lacked access to resources. For example, those with resources such as land practiced crop rotation. Those with access to internet accessed climate information to plan properly on their farming activities. A few farmers with access to resources, especially from interventions by government, adopted more than one strategy such as fertigation, shade nets, drip pipes, agricultural inputs and machinery and implements. Many farmers increased their production with drips and agricultural inputs. Interventions by government increased the adaptive capacity of farmers. These strategies enabled a few farmers to adapt to high temperatures and droughts. Hence, the study found that high adaptive capacity requires more investment of agricultural technologies.

There are lessons to be drawn from nations like Mali, Mozambique and Indonesia. Farmers in these nations employed free innovative techniques including seed development and water collection through the construction of earthbunds and zais, which served the purposes of lowering crop failure and collecting water. In Indonesia, farmers engaged in non-agricultural occupations in addition to agriculture to increase their income. In Mozambique, farmers produce and sell charcoal as additional income from agriculture (Martinho & Kreisler 2010)

Objective 4: To assess the challenges encountered by smallholder farmers when adapting to climate change

Factors limiting smallholder farmers from practicing adaptation measures helped to achieve this objective. Infrastructural, technological, financial, environmental and institutional challenges, such as water, energy, roads, markets, and a lack of extension support were discussed in Chapter 2. Table 4.8 in Chapter 4 found that some adaptation challenges encountered by respondents were inadequate capital, high temperatures, high agricultural inputs, a lack of access to land, a lack of climate information, a lack of water and the COVID-19 outbreak. COVID-19 came as an additional challenge to farmers. These sections together with a lack of resources, which is Theme 4 in Chapter 4, show how the objective has been achieved. The objective draws out support from stakeholders through collaboration.

Objective 5: To analyse factors motivating smallholder farmers in Limpopo to adapt to climate change and to provide solutions on how to improve adaptation at farm level

Intrinsic and extrinsic motivation, discussed in Chapter 2, achieved this objective. It was found that incentives and rewards play a crucial role in motivating individuals to take prevention measures for climate events. According to Woods, Nielsen, Pedersen, and Kristofersson (2017:65), beliefs and fears about the effects of climate change serve as the driving force behind adaptation.

For instance, farmers who experienced crop reductions or losses have a greater willingness to adjust than farmers who have not. Information about risks, according to Frank, Eakin and Lo'pez-Carr (2011:67), also inspired people to adjust. Despite that LDARD has introduced strategies like the CASP programme, relief incidence and disaster grants to address climate change, farmers' lack of climate information and government support are extrinsic motivations that slowed the pace of adoption of adaptation strategies. However, according to the findings, the support from government was inadequate to encourage and motivate some farmers to implement adaption techniques. These farmers were unable to take advantage of some of the government's infrastructure support due to a lack of money to connect electricity. Accessibility and availability of bank institutions can motivate farmers to adapt to climate change. These findings are aligned to Phuong et al (2017) who found that the availability of suitable information, new methods, and government support motivated farmers to adapt to climate change in order to provide food and support their families through education.

5.4 Study contribution

1. It is hoped that the study's findings will be presented in conference proceedings and published in articles to inform researchers about current climate change information and dissemination of information to audiences such as decision makers, scholars, government officials, farmers and other climate change stakeholders.

2. This work contributes to the current body of knowledge by expanding on previous climate change studies, helping other researchers to better understand and expand on the topic.

3. This research fills the policy gap by providing evidence-based

information for advancement and decision-making in the sector and the field.

4. The study fills a methodological vacuum by outlining the process and instrument used to collect non-verbal data to assist researchers to incorporate non-verbal communication when conducting research.

5. The study is among the first to employ a sequential mixed exploratory technique in the field, using qualitative findings to create a quantitative data gathering instrument to assist other researchers in using the same instrument in future.

6. The study contributes to using diverse methods for data gathering and analysis, as well as integrating results using data joint display for improved understanding.

7. The study explains how farmers' contribute in reducing greenhouse gas emissions and improving agricultural production.

8. The study fills the practical gap by suggesting practical steps for improving adaptation at farm level

5.5 Conclusion of the study

The study was conducted to reveal how smallholder farmers of GRASP secondary cooperative in Limpopo Province understand climate change and to analyse the strategies adopted and practiced by these smallholder farmers.

It emerged from the findings that the negative impacts of climate change affect and will continue to affect agriculture and the farming sector which is the main source of smallholder farmers' livelihoods. This is because the temperature is projected to continue to increase in the coming years. Extreme climatic events, such as heavy rainfall resulting in flooding and high temperatures resulting in droughts, exacerbated the living conditions of smallholder farmers since livestock mortality increased and crops were damaged and destroyed leaving farmers with no income. These are the results of human activities such as deforestation for expansion of farming activities, and provision of basic needs due to population growth contributing significantly to the GHGs emissions.

Despite smallholder farmers' lack of adaptive capacity which limits them from taking precautionary climate change measures, smallholder farmers always discover ways to survive the extreme climatic events. Smallholder farmers believed that extrinsic motivation through government support can pave their way to adopt and implement adaptation measures. Hence the majority of the strategies they have adopted are the result of government support, albeit the assistance was found to be insufficient due to stakeholders working in silos. Appropriate strategies adopted through government support included: access to land, fertigation, shade nets, boreholes, mechanisation, agricultural inputs and drip irrigation pipes.

A few smallholder farmers were found to be underutilising some of the government-supported adaptation techniques. These farmers lacked the funds to connect to and pay for three-phase electricity to supply power to the shade nets. The inappropriate criteria for selecting farmers who received assistance were discovered to be the main reason for shade net underutilisation. Mulching, crop rotation, application of manure, changing planting seasons, planting bambara groundnuts and okra were among the strategies smallholder farmers used at less or no cost. These approaches can save farmers money on inputs for agriculture that are too expensive for many farmers in the research area.

Support from government had a positive impact of increasing crop yields and creating more jobs for smallholder farmers who received support. Provision of drip irrigation pipes, fertigation, shade-nets, agricultural inputs like seeds, pesticides, fertilisers, and farm machinery are some of the supports that improved crop yields. Planting indigenous crops, such as bambara groundnuts, groundnuts and okra, was an additional practice that may be applied by smallholder farmers in the study area because these crops can withstand and flourish under harsh weather conditions. However, smallholder farmers alone cannot survive the impacts of climate change as they require sufficient resources.

The findings showed that climate change stakeholders underestimated the role of smallholder farmers hence minimal support was received from very few institutions. Functional institutions are essential for decreasing climate vulnerability and improving progress (Sietz, Boschu & Klein 2011). For example, some farmers were evicted while others received inadequate support from extension services. This displays the importance of smallholder farmers' accessibility to resources which requires high self-efficacy and high adaptive capacity to address the threat caused by extreme climatic events. These impediments, along with a lack of both financial and non-financial resources, intensified the climate change effects felt by smallholder farmers as they incurred high socioeconomic losses of crop yields, income, jobs, and even food. Addressing climate vulnerability necessitates the availability of human resources with sufficient climate-specific experience and the ability to network and collaborate on climate challenges. Few officials, according to the findings, were trained on climate change. The migration of new exotic pests into the country, such as grasshoppers, which wiped out farmers' fields in the study area, highlights the importance of educating officials on how to cope with these situations, which are likely to occur in the near future owing to climate variability.

A lack of knowledge on how to manage exotic pests and diseases, including armyworm, fruit flies, and tuta absoluta, may prevent farmers from adopting and employing adaptation strategies. These resources and skills are critical for assessing the threat of climate change and developing relevant strategies and development requirements. Maponya and Mpandeli (2013) cite a lack of human resources as a major impediment for farmers to adapt to climate change.

The consequences of these losses are increased poverty and a lower contribution of the agriculture sector to the economic growth of the country. The NDP's vision of the millions of jobs to be created by smallholder farmers would not be achieved unless the barriers that impede smallholder farmers from adopting and executing climate change adaptation measures are addressed. Inadequate capital, high temperatures, high agricultural input costs, a lack of access to land, climate information, water, and labour and the COVID-19 outbreak were some of barriers preventing smallholder farmers from adopting and implementing adaptation strategies. Many rural people's livelihoods are dependent on agriculture and if the country fails to address these barriers, the SDGs will never be achieved.

Farmers' livelihoods and food security can be improved, vulnerability and poverty can be reduced, more jobs can be created, agricultural production , crop yields, and farmers' adoption of adaptation strategies can also be improved if stakeholders recognise the socioeconomic roles of smallholder farmers and collaborate to address the barriers impeding smallholder farmers from adopting climate change adaptation strategies

Generating income from farming for better access to education for children and the provision of food to families motivated farmers to adapt to climate change. Fear of the threat of climate change also motivated farmers to adopt and practice some strategies. Other factors that motivate many farmers to adapt to climate change are support from government through the provision of agricultural equipment, such as tractors, drip pipes, and agricultural inputs such as seeds, fertilisers and chemicals.

A high adaptive capacity is a pre-requisite for the agriculture sector to cope and address extreme climatic conditions and to enhance the adoption of adaptation strategies by farmers. These require investments in both farm and non-farm infrastructure, such as roads, technologies, education, energy, dams, reservoirs and drips, to cater for water scarcity which impacts negatively on crop yields. Human investment is also critical as smallholder farmers depend on extension officers to make informed decisions.

5.6 Recommendations

The above findings prompted the researcher to provide recommendations that may be effective in addressing the problems encountered by smallholder farmers in Limpopo when adapting to climate change.

Firstly, both smallholder farmers and key informants understand that climate change is real. Many smallholder farmers linked climate with high temperatures and heavy rainfall resulting in drought and floods. From key informants, climate change was linked to incidents such as frost, hail, disasters, droughts, floods, and the invasion of pests that destroyed many farms. Experts linked climate change to its causes by humans including agricultural and natural activities contributing to GHG emissions that impact negatively on people's livelihoods. The LDARD, together with climate change stakeholders, should convey climate change information to all smallholder farmers through the creation of awareness during information days, farmers' days, and roadshows to enable farmers to protect themselves from extreme climatic conditions.

Secondly, smallholder farmers have embraced and are implementing low-cost adaptation measures, such as manure application and mulching, which decrease the current high costs of agricultural inputs. These strategies can save farmers money because they buy expensive inputs such as seeds, fertilisers, and chemicals every planting season. According to key informants, drought-tolerant seeds cannot be reused in the following planting season because they are not recyclable, unlike traditional silos that were utilised by elders in the past to store reusable seeds. To bridge the gap between modern technologies and traditional farming, it is crucial to communicate the benefits of traditional farming and technological farming to smallholder farmers and urge them to embrace and execute them in order to decrease vulnerability and poverty in the country through increased agricultural production. Further investigation is needed to explore crops that use less water in the study location.

Thirdly, findings revealed that smallholder farmers were not receiving adequate support. Some of the restrictions preventing smallholder farmers from adapting to climate change include a lack of access to resources such as land, water, finance, extension support, and climate change awareness. This could be because officials discovered flaws in the criteria used to select farmers to support. Farmers have been neglecting to use government-provided technology assistance. To address this gap, the government must adjust policies or programmes to enable them to fully support smallholder farmers to avoid wasteful expenditure.

The government needs to develop an impact monitoring tool to collect information regarding the impact of the support given to smallholder farmers. The tool's outcome will help the department to identify gaps and make informed decisions on what ought to be done to improve the support. Collaboration amongst stakeholders, such as traditional leaders, bank institutions, and various government departments, is also required to pool both financial and human resources in order to provide full support to smallholder farmers in overcoming barriers that prevent them from adopting and implementing adaptation techniques. These will improve availability and accessibility of resources to farmers.

Fourth, LDARD and other institutions should invest in human resources by ensuring that officials' knowledge improves through continuous education so that they can advise farmers on how to manage new exotic diseases and pests brought on by climate change and other events as they emerge. To protect livelihoods and for agriculture to contribute meaningfully to the country, the LDARD must be proactive and appoint crop protection specialists in all local municipalities in Limpopo Province, where there are now only two crop protection experts. The findings, for example, revealed a dearth of understanding regarding grasshoppers that had relocated to Selwane which requires continuous training of officials to improve on coping with negative climatic effects. According to the findings, officials were unable to reach the area due to a shortage of transportation, and farmers' fields were destroyed. Based on this, there is a need to make resources available to enable officers to reach farmers' fields whenever they are needed.

Allocation of resource was found to be gender bias. Further research needs to be undertaken to study the gender dimensions of climate change and adaptation. Investing in agriculture infrastructure such as dams, reservoirs, drips, and renewable energy will improve farmers' yields thereby reducing vulnerability and poverty in rural areas through improving the livelihoods of the poor by creating jobs and securing food. Further investigation is needed to explore crops that use less water in the study location.

5.6.1 Proposed steps to effective adaptation

For planned adaptation which needs stakeholders' intervention including government as a key role player, the researcher suggests coordination identification and involvement of critical climate stakeholders during climate planning sessions. It is of this reason that government, the private sector, civil society, and development partners and other important partners must work together to successfully incorporate climate risk into the delivery of national and regional development. This means stakeholders would participate, prioritise and incorporate climate change activities into their plans, commit their resources, know their roles and responsibilities, their channels of reporting and time frames to achieve their commitments. The following steps show how stakeholders' commitment could be achieved:

5.6.2 Establishment coordination of a stakeholder forum on climate change

A stakeholder forum will be able to conduct stakeholder identification to develop a stakeholder analysis report in a specific region and define each stakeholder's roles and duties. Following the completion of the stakeholder analysis, the next stage will be to create a memorandum of agreement in which all climate change stakeholders accountable for a specific area will direct their resources by signing the MOA. Accountability entails reporting on how certain tasks were done or progress was made toward a specified objective. This underlines the need to be clear about what is expected of and by each actor. Accountability necessitates openness, therefore the two are inextricably linked in practice. Mutual accountability between funders and beneficiaries is related to effective adaptation for accountability to fulfil its potential (Klein, Adams, Dzebo, Davis & Siebert 2017).

The findings revealed only two government departments that supported financially through grants and non-financially through skills development. The coordination of stakeholders would accelerate the adoption of strategies by smallholder farmers since support will be channelled from government and non-government departments thereby minimising the barriers smallholder farmers encountered when adapting to climate change. This commitment would also be available to their plans, as budgeting and non-financial resources, such as human resources, work hand in hand.

5.6.3 Formation of a profiling team

The findings revealed that government support does not respond to the needs of farmers. Therefore, establishing a profiling team to create an instrument that would help in identifying the needs of smallholder farmers in relation to climate change is recommended. The profiling team would also be able to conduct profiling and compile profiling reports for the forum on a quarterly basis. During the presentation of the profiling report, each stakeholder would identify and agree with the other stakeholders on the areas of intervention outlined in the report.

5.6.4 Signing of the Memorandum of Agreement by stakeholders

Farmers had no control over the effects of climate change, and the conclusion disclosed a lack of commitment by stakeholders. Hence, it is critical for stakeholders to commit themselves, through signing the MoA to work together with other stakeholders. By signing the MoA, stakeholders would commit resources, such as funding and human resources, to implement the identified needs of farmers from the profiling report. The commitment of stakeholders would then be preceded by implementation.

5.6.6 Reviewing of current climate change policies

The forum will also ensure that existing policies are scrutinised to assess whether they meet the needs of smallholder farmers. If existing policies are found to be ineffective in meeting the needs of farmers, it is suggested that policies should be revised or amended to incorporate their needs.

5.6.7 Implementation

The researcher recommends the development of an implementation plan by stakeholders which is to include start and completion timeframes, and a list of resources necessary to complete the project. Implementation will be based on the needs of smallholder farmers as identified in the profiling report. For example, if the study uncovers a water problem in the profiled farms, organisations responsible for water (as indicated by stakeholder roles and responsibilities) would commit to a water project and make funds available to address that challenge.

5.6.8 Monitoring of impact and implementation

Each institution must provide a monitoring instrument that will help in tracking the project's progress and ensuring that it stays on schedule as agreed upon when the MoU is signed. The impact must be evaluated when the project is completed. A water project, for instance, would result in increased irrigation for farmers, which would increase crop yields. The benefit would then be to monitor the impact after support. For example, how much is the production per hectare after support and how many smallholder farmers access water after support? These are the questions to be explored further by other researchers in the field of climate change and climate adaptation.

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Annexure A: Ethics approval

ANNEXURE A

UNISA university of south africa

COLLEGE OF HUMAN SCIENCES RESEARCH ETHICS REVIEW COMMITTEE

23 April 2021

Dear Queen Mabunda

Decision:
Ethics Approval from 23 April 2021 to 23 April 2026

NHREC Registration # :
Rec-240816-052
CREC Reference # :
64138771_CREC_CHS_2021

Researcher(s): **Queen Mabunda**
Contact Details: 64138771@mylife.unisa.ac.za

Supervisor(s): **M. Rakolojane**

Title: An analysis of climate change strategies: A case study of smallholder farmers in Limpopo Province, South Africa

Degree Purpose: PhD

Thank you for the application for research ethics clearance by the Unisa College of Human Science Ethics Committee. Ethics approval is granted for five years.

The ***Low risk application*** *was* ***reviewed on the 23 April 2021*** by College of Human Sciences Research Ethics Committee, in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and 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 should be communicated in writing to the College Ethics Review Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the

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confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.

5. 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. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
7. No fieldwork activities may continue after the expiry date **(23 April 2026).** Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **64138771-CREC_CHS_2021** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Signature : pp

Prof. KB Khan
CHS Ethics Chairperson
Email: khankb@unisa.ac.za
Tel: (012) 429 8210

Signature : PP

Prof K. Masemola
Exécutive Dean : CHS
E-mail: masemk@unisa.ac.za
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Annexure B: Request for permission to conduct research

ANNEXURE B

GRASP FARMERS SECONDARY COOP Reg No 2017/001126/25
P.O.Box 1803 Letsitele 0885 Contact Number: 081 052 1158 / 072 664 7264

Request for permission to conduct research at Gravelotte Selwane Priska farmers co operative

26 November 2020

Dear Queen

The co-operative has received your request to conduct research in our area and has taken a resolve to grant you access to the cooperative's member farmers. We believe as the cooperative that the study will bring about novel ideas in dealing with climate change and thus will affect farmers positively.

the cooperative would in turn ask that all contribution of the farmers, whether information , time and effort be handled with the utmost care, courtesy and respect ,we therefore wish you a successful and impactful study

Regards

Jack Moradu
Chairperson

Eunice Mashao
Secretary

Annexure C: Application to carry out research

ANNEXURE C

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
AGRICULTURE AND RURAL DEVELOPMENT

Ref: 12R
Enquiries: Dr T. Raphulu

13 July 2023

Mabunda Queen
UNISA

RE: APPLICATION TO CARRY OUT RESEARCH UNDER THE DEPARTMENT OF AGRICULTURE & RURAL DEVELOPMENT

1. Kindly take note that your request to conduct research titled "***AN ANALYSIS OF STRATEGIES TO CLIMATE CHANGE ADAPTATION: A CASE STUDY OF SMALLHOLDER FARMERS IN LIMPOPO PROVINCE"***, has been granted. The permission to conduct research in the department is valid from 17th July 2023 to 29th March 2024.

2. The permission entails interviewing 10 officials from the Limpopo Department of Agriculture and Rural Development working with smallholder farmers. You are required to contact the office of the Deputy Director : Mopani East to brief them on the study, to request up-to-date list of officials working with smallholder farmers, participation and assistance.

3. Kindly take note that you will be expected to hand over a copy of your final report to the Department for record purposes. You may also be invited to share your findings in the Departmental Research Forum.

4. Hoping that you will find this in order.

Kind regards

Dr. T. Raphulu
Chairperson: Research Committee

13/07/2023
Date

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

The heartland of Southern Africa - development is about people!

Annexure D: Consent to participate in the study

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ANNEXURE D: CONSENT TO PARTICIPATE IN THIS STUDY

I, ________________(Name and Surname of participant) confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the focus group discussion/ interviews/completion of questionnaire.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname ________________

Participant Signature________________Date______________

Researcher's Name & Surname______________

Researcher's signature: ____________ Date: ____________

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Annexure E: Confidentiality Agreement

UNISA university of south africa

ANNEXURE E: CONFIDENTIALITY AGREEMENT

Dear Mr/Mrs/Ms………………

You have been appointed to collect/transcribe data for Queen Mabunda, on the research project "An analysis of climate change adaptation strategies: A case study of smallholder farmers in Limpopo Province, South Africa".

The ethical guidelines of this study need that you read, understand and sign this form indicating that you are willing to enter into a confidentiality agreement with respect to the data to be collected/transcribed in this study. The study will use audio recorders and camera where identification of participants could easily be recognized. Having access to this information requires you to protect participants who wish to be anonymous and keep their information confidential. You are further required to leave no material unattended when not being used. Moreover, you need not to discuss anything with anyone regarding participants and data collected in this study except with principal investigators.

By signing below you agree that you have read and understood the agreement and that you will abide by the rules as specified by following UNISA Policies:

- Unisa Research Policy
- Unisa Ethics Policy
- Unisa IP Policy
- UNISA SOP for Risk Assessment
- Unisa COVID-19 guidelines

Name…………………………………………

Contact no……………………………………

Email address………………………………...

Signature………………………………………

Date……………………………………………

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Annexure F: Focus Group Guide

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ANNEXURE F: FOCUS GROUP GUIDE	
An analysis of climate change adaptation strategies: A case study of smallholder farmers in Limpopo Province, South Africa.	
Date	
Research Assistant	
Focus Group Discussion	
Village	

Welcome

Thank you for volunteering to take part in this focus group. You have been asked to participate as your point of view as a farmer and community member is important. Your time and input is appreciated.

Introduction

This focus group discussion is designed to better understand your thoughts and feelings about climate change and how you were impacted by the effects of climate change and what adaptation strategies have you adopted to cope with these impacts. The focus group discussion will take no more than two hours. May I tape the discussion to facilitate its recollection?

Anonymity

Despite being taped, I would like to assure you that the discussion will be anonymous. The tapes will be kept safely in a locked facility until they are transcribed word for word, then they will be destroyed. The transcribed notes of the focus group will contain no information that would allow individual subjects to be linked to specific statements. You should try to answer and comment as accurately and truthfully as possible. I and the other focus group participants would appreciate it if you would refrain from discussing the comments of other group members outside the focus group. If there are any questions or discussions that you do not wish to answer or participate in, you do not have to do so; however please try to answer and be as involved as possible.

Consent

Please assure that you have completed a consent form. One copy of the informed consent form should be given to me and you should keep the second copy for your records.

Ground rules

- ✓ The most important rule is that only one person speaks at a time.
- ✓ One person should speak and finish without any interruption by others
- ✓ There are no right or wrong answers.
- ✓ Maximum participation is required as all your views are important
- ✓ You are requested to not disturb the discussion by putting your phones on silence.
- ✓ When you do have something to say, please do so by raising of a hand.
- ✓ You do not have to agree with the views of other people in the group but please respect their views
- ✓ Does anyone have any questions?
- ✓ OK, let's begin

1. Opening questions

1.1. Reflect on your experiences about climate change in your area. Would anyone share those experiences with us?

2. Guiding questions

2.1. How does/has climate change affect/affected agriculture in your area

2.1.1. How climate change affected your production?

2.1.2. How were you affected by natural disasters?
2.1.3. Explain how climate change affected your income?
2.1.4. How has climate change affected your livelihoods?
2.1.5. How would you describe your contribution towards food security?
2.1.6. What did you do to surpass all these challenges?

2.2. What strategies are you applying/ have you applied to ensure that you adapt with the effects of climate change.

2.2.1. Explain how the strategies helped you?
2.2.2. Explain how was your production after adopting these strategies?
2.2.3. How were the livelihoods improved?
2.2.4. How your income has been improved?
2.2.5. How can climate change strategies be improved?

2.3. What challenges are you encountering when adapting to the effects of climate change

2.3.1. Discuss the challenges you are/ have been encountering?
2.3.2. Describe the level of your adapting capacity?
2.3.3. Discuss how financial resources assisted you to address these challenges?
2.3.4. Discuss how non-financial resources helped you to address these challenges?
2.3.5. Are there any resources not mentioned above you need to share with us?
2.3.6. How can climate change challenges be addressed?

2.4. What motivates you to adapt to climate change?

2.4.1. Briefly explain your motivation factors?
2.4.2. What do you think need to be done to improve adaptation at farm level?

2.5. From what has been discussed today, reflect on the most important issues.

3. Ending question

Is there anything connected with climate change adaptation strategies which has not been discussed that you feel strongly about and would like to bring up now?

<u>Thank you, your participation in this study is much appreciated</u>

Annexure G: Questionnaire for smallholder farmers

ANNEXURE G: QUESTIONNAIRE FOR SMALLHOLDER FARMERS IN LIMPOPO PROVINCE, SOUTH AFRICA.

This questionnaire is for collection of data towards a PHD degree at University of South Africa (UNISA). The purpose of the survey is to analyse climate change adaptation strategies. A case study of smallholder farmers in Limpopo Province, South Africa. Interviewees are requested to participate voluntarily.

Instruction: Respondents are requested to mark the appropriate boxes with an X.

1. Gender?

Female	
Male	

2. Age?

18-30	
31-39	
40-49	
50-59	
Above 60	

3. Educational level?

No education	
Grade 12	
Diploma	
Degree	
Other: Specify	

4. Source of income?

Agricultural	
Non-agricultural	
Other: Specify	

5. What is your experience in farming?

Number of hectares	
>6 years	
6-10 years	
<10 years	

6. What is the size of your land?

Number of hectares	
<6 hectares	
6-10 hectares	
>10 hectares	
Other: Specify	

7. Climate change affects agriculture negatively?

Agree	
Strongly agree	
Disagree	
Strongly disagree	
Uncertain	

If your answer is agree or strongly agree, please answer question 8.

8. Please explain how climate change affected agriculture.

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9. Farmers have experienced climate change?

Yes	
No	

If your answer is yes in question 9, please answer question 10.

10. What is your climate change experience?

Extreme climatic events	
Low crop yield	
Water scarcity	
Food shortage	
Other: Specify	

11. Choose the adaptation strategy you are practicing

Fertigation	
Drip irrigation	
Crop rotation	
Mulching	
Shade nets	
Boreholes	
Land expansion	
Not adapting	
Manure (Chicken & cattle)	
Other: Specify	

12. Explain the benefits of your chosen strategy in question 11

…………………………………………………………………………

…………………………………………………………………………

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13. The challenge farmers experience when adapting to climate change

Inadequate capital	
High temperature	
Lack of access to climate change information	
Lack of access to land	
Lack of access to water	
COVID 19	
Other: Specify	

14. Indicate how you addressed the challenge in question 13

…………………………………………………………………………..

……………………………………………………………………………

……………………………………………………………………………

15. Adaptation at farm level need to be improved?

Yes	
No	

If answer is yes in Question 16, please answer question 16.1

16.1 How can adaptation at farm level be improved?

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

Thank you for participating in this research

Annexure H: Key Informants' interview guide

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ANNEXURE H: KEY INFORMANTS INTERVIEW GUIDE	
An analysis of climate change adaptation strategies: A case study of smallholder farmers in Limpopo Province, South Africa.	
Date	
Name of researcher	
Name of Institution	
Venue	

Welcome

Thank you for volunteering to take part in this interview. You have been asked to participate as your point of view as a government official is important. Your time and input is appreciated.

Introduction

This interview is designed to better understand your thoughts and feelings about climate change and how smallholder farmers you are servicing are impacted by the effects of climate change and what adaptation strategies they adopted to cope with these impacts. The interview will take no more than 1 hour. May I tape the discussion to facilitate its recollection?

Anonymity

Despite being taped, I would like to assure you that the discussion will be anonymous. The tapes will be kept safely in a locked facility until they are transcribed word for word, then they will be destroyed. The transcribed notes of the interview will contain no information that would allow individual subjects to be linked to specific statements. You should try to answer and comment as accurately and truthfully as possible

Consent

Please assure that you have completed a consent form. One copy of the informed consent form should be given to me and you should keep the second copy for your records.

1. Opening questions

1.1. Reflect on your experiences about climate change. Would you share those experiences with me?

2. Guiding questions

2.1. What is your official role in climate change?

2.2. What climate change trainings/workshops/conferences have you attended since joining this institution?

2.3. What climate change programmes/projects are offered by your institution?

2.4. How does your institution support smallholder farmers impacted by climate change?

- 2.4.1. Explain financial support
- 2.4.2. Explain non-financial support
- 2.4.3. Explain how climate information is disseminated to smallholder farmers?

2.5. How does/has climate change affect/affected agriculture?

- 2.5.1. Explain how smallholder farmers production is affected?
- 2.5.2. Explain how livelihoods are affected?
- 2.5.3. What did you do to assist farmers to surpass all these challenges?

2.6. What are most common climate disasters in the area you serve?

2.7. What strategies do smallholder farmers use to deal with the consequences of climate change?

2.8. Which strategies can you recommend and why?

2.9. How can smallholder farmers be encouraged to use adaptive strategies?

2.10. From what has been discussed today, reflect on the most important issues.

3. Ending question

3.1. Is there anything connected with climate change adaptation strategies which has not been discussed that you feel strongly about and would like to bring up now?

<u>Your participation in this study is much appreciated</u>

Annexure I: Matrix Table

ANNEXURE I

Matrix Table: Assessment of level of agreement between focus group members

A= Agreement by participant (verbal or non-verbal)

D= Disagreement by participant (verbal or non-verbal)

IE= Important statement or example indicating agreement

ID= Important statement or example indicating disagreement

WR= Participant did not agree or disagree (Without response)

Questions	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Focus Group 1						
Experience of climate change						
Impacts of climate change on agriculture						
Strategies for coping with climate change						
Challenges encountered when adapting to climate change						

Annexure J: Editor's letter

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To whom it may concern

This letter serves to inform you that I have done formatting, language editing and reference checking on the thesis

AN ANALYSIS OF CLIMATE CHANGE ADAPTATION STRATEGIES: A CASE STUDY OF SMALLHOLDER FARMERS IN LIMPOPO PROVINCE, SOUTH AFRICA

By

QUEEN MABUNDA

Barbara Shaw

29/08/2024