SMALLHOLDER FARMER LIVELIHOOD STRATEGIES FOR COPING AND ADAPTING TO DROUGHT IN THE LIMPOPO PROVINCE, SOUTH AFRICA

by

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DECLARATION

I, **Sydney Shikwambana**, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

25 March 2024

Signed **Date**

ABSTRACT

Drought is a natural phenomenon which causes widespread socio-economic and environmental challenges. The increasing frequency and intensity of drought events is negatively impacting on smallholder farmers' livelihoods. The challenges related to drought are compounding existing water and food insecurity worldwide. There is an urgent need for coherent strategies that drive towards sustainable development by 2030 as proposed by the United Nations General Assembly's (UNGA) Sustainable Development Goals (SDGs), mainly Goals 1 (no poverty) and 2 (zero hunger) in poor rural communities. This study assessed rainfall and temperature trends from 1960 to 2018 and the impacts on crop production in the Mopani and Vhembe Districts of Limpopo Province, South Africa. Trend analysis was used to assess rainfall patterns, as well as the trends in temperature recorded for the past 58 years. The climate moisture index (CMI) and runoff estimates were used to assess the degree of aridity and water availability, respectively. Geographic Information Systems (GIS) and remotely sensed data were used to assess the changes over time. As part of the assessment and analysis of drought, multiple sources of data were consulted, including 200 households' socio-economic information, focus group discussions, interviews and geospatial analysis. Climate change adaptation were observed in smallholder farmers through planting early maturing plants and drought-tolerant crops, altering planting dates, crop diversification, and irrigating in addition to non-farming activities. The study used the Household Economy Approach (HEA) to characterise and classify smallholder farmers in the Mopani and Vhembe districts of the Limpopo Province using socio-economic, geographic, and ecological factors. Results show that indeed, much diversification exist within smallholder farmers, each deploying specific strategies towards more resilient livelihood outcomes. The key factors that underpin the classification of smallholder farmers and determine livelihood strategies include sources of income, level of education, national social grants, production activities, tangible assets, household characteristics and other factors. Therefore, the one-size-fits-all definitions do not apply in the two districts. It is therefore ideal for a livelihoods analysis to be conducted whenever there are interventions to be made for smallholder farmers to adequately inform them and enhance their effectiveness. Policy and decision-makers should focus on enhancing adaptation and resilience initiatives in the study areas through systematic, transformative, and integrated approaches, such as scenario planning, circular economy, and nexus planning. The smallholder farmers are classified as poor, middle, and better off in order to assist them during drought periods.

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DEDICATION

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GLOSSARY

ADMP	Agricultural Drought Management Plan
ARC	Agricultural Research Council
CGS	Council for Geo-sciences
CASP	Comprehensive Agricultural Support program
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEWS	Drought Early Warning System
DPME	Department of Planning, Monitoring and Evaluation
DEA	Department of Environment Affairs
EWS	Early Warning Systems
ENSO	El Niño Southern Oscillation
FSP	Farmer Support Program
FAO	Food and Agriculture Organisation of the United Nations
IGCCC	Intergovernmental Committee on Climate Change
NDA	National Department of Agriculture
SAVAC	South African Vulnerability Assessment Committee
SDGs	Sustainable Development Goals
SAWS	South African Weather Service

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Overview

This chapter is intended to provide an overview of the concepts of drought, vulnerability, smallholder farmer livelihood characteristics and strategies; research issue, background information, and summary of the problem to be studied; research question, objective, and conceptual framework are discussed; the study's scope and significance are explained, and a priori conceptual framework is proposed. A brief description of the research design and analysis, focusing on the distinct areas covered and the rationale for the study;specify the present research setting as an international business context; outline the report's strengths, limitations, and contribution to the body of knowledge and practice.

1.2 Introduction

South Africa is experiencing frequent climate extremes such as droughts and flooding due to the recurrence of the El Niño Southern Oscillation (ENSO) phenomenon. The ENSO is causing below-normal rainfall, high temperatures and shortened rainfall seasons. For example, during the latter part of the 2015/16 summer season; the country experienced one of the strongest El Niño episodes which caused severe drought in the entire sub-Saharan Africa region (BFAP, 2016; DAFF, 2016). The low rainfall resulted in dry conditions with drought emergencies being declared in the provinces of the Limpopo, Western Cape North-West, KwaZulu-Natal, Mpumalanga, and the Free State (Nhamo *et al*., 2019; BFAP, 2016; DAFF, 2016). Although the situations improved in 2017 with increasing dam water levels in most of the provinces, the Western Cape Province continued to experience severe water shortages into 2018. The 2015/16 drought adversely affected all sectors as evidenced by rising food prices and shortages, loss of employment and rural-to-urban migration (BFAP, 2016; DAFF, 2016). Crop failure also resulted in low national economic growth, as well as deteriorating environmental conditions (DAFF, 2016). As the recurrence of climate extremes continue to increase in frequency and intensity, the smallholder farmers are the most affected as they are the most vulnerable as they lack resources to adapt (Shikwambana *et al*., 2021; Schilling *et al*., 2020; Nhamo *et al*., 2019; Mpandeli *et al*., 2019; Petrie *et al*., 2015).

By mid-2016, a total of 246 425 farmers were reported to be affected by the drought throughout the country (DAFF, 2016; SAVAC, 2016). Furthermore, approximately 252 900 livestock loss was recorded, while 9 340 508 livestock were still vulnerable by the end of 2016 (DAFF, 2016). Crop farmers could not plant during the planting season due to inadequate rainfall. According to the analysis of the South African Vulnerability Assessment Committee (SAVAC), the number of people directly affected by the drought was 6 2291 900 across South Africa. Out of this number, 2 516 800 people were the poor, and in particular, the very poor were the worst affected by the drought, and their livelihoods remain vulnerable (SAVAC, 2016). Taking these factors into consideration and the recurrence of drought and flooding in the country, as well as the smallholder farmers vulnerability . There is an urgent need to develop some adaptation frameworks to assist smallholder farmers from the vagaries of climate change.

The term smallholder farmer refers to cultivators with relatively small farms of around two hectares or less in rural areas who practice intensive, permanent agriculture with an emphasis on diversification (Mudhara, 2010). There are various facets of smallholder farming and in countries such as South Africa; the term tends to carry various connotations relating to the history of the country (van Averbeke & Mohamed, 2006). The understanding of smallholder farmer characteristics is generally a complex issue. There are diverse groups of smallholder farmers whose needs are also varied, and there is limited understanding of how these farmers derive their livelihoods, especially during disaster periods such as droughts (Ncube & Lagardien, 2018). Past studies have classified smallholder farmers based on socio-economic and bio-physical variables that included the agro-ecological conditions which determine the density of the population and the potential agricultural production, as well as market access (Shikwambana & Malaza, 2022; Mekuria *et al*., 2021; Elbendary *et al*., 2017; McDowell *et al*., 2012; Julia *et al*., 2012; Jordaan, 2011).

Farming styles are defined by van Averbeke & Mohamed (2006) as a way of organizing the activities involved in agricultural production and combining them in the right way.Classifying farming styles is important because it recognizes that farmers are not homogenous, whether they are grouped according to resource endowments, farming methods, risk management or technology adoption. By using the farming styles approach, van Averbeke & Mohamed (2006) classified farmers into three groups: 'employers' who employed full-time labourers, 'food farmers' who produce primarily household foods, and 'profit makers' who farm primarily for the purpose of selling and generating significant incomes.

The usage of direct and to a great extent top-down methodologies that don't adequately perceive smallholder farmers' many-sided quality as basic, has brought about agricultural innovative work endeavours creating lower than anticipated effects on farmer livelihoods (Chikowo *et al*., 2014). Innovation created at research stations has frequently neglected to enhance profitability at the farm scale, because of gross crisscross of exceedingly factor conditions when they are exchanged for use by various cultivating families. Some portion of the issue has been the sweeping advancement of single innovations that disregard the farmers' assets and capacities, and the inability to address generation goals and imperatives crosswise over various sorts of ranches (Chikowo *et al*., 2014).

Implementation of evidence-based adaptation strategies would protect and improve smallholder farmer's livelihoods and save aid resources from government and aid agencies. A livelihood strategy, according to Dorward *et al*. (2009), engages household assets to provide yields as well as contribute towards future activities and assets. Smallholder farmers apply livelihood theory to increase household agricultural productivity for home comsuption and generate income for future investment because they combine assets in activities (Ncube, 2017).

A study by Dorward *et al*. (2009) proposes three types of livelihood strategies: stepping up, stepping out, and hanging in. 'Hanging in' households are those that maintain livelihood levels in spite of adverse socioeconomic circumstances by holding assets and engaging in activities. The 'stepping up' households increase their production and income by investing in assets, so that their livelihoods are improved. The 'stepping-out' households are engaged in existing activities to accumulate assets, which in turn provides them with the opportunity to diversify into other livelihood strategies that turn out to be relevant in the future. Farming styles are compared with livelihood strategy approaches for determining the correlation between farmers' farming approaches and livelihood development trajectory. According to van Averbeke & Mohamed (2006) argue that certain lifestyles are strategic and structurally corresponding to certain livelihoods.

There is a greater risk of drought for smallholder farmers than for their commercial counterparts because they do not possess the resources and ability to deal with adverse climate conditions like drought without external support (Shikwambana *et al*., 2021; Schilling *et al*., 2020; van Koppen *et al*., 2017; Petrie *et al*., 2015). Support can come from anywhere, whether from family members, friends, government, or international community (Jordaan, 2011). There is, therefore, need to understand the production means of different types of farmers in order to develop appropriate ways of supporting them to improve their livelihoods. All aspects of smallholder farmer livelihood strategies need to be considered, including household asset positions, institutions, power structures, and market policies play an important role in the production environment.

The development of a drought preparedness mechanism to cushion the resource poor smallholder farmers will go a long way in building drought resilience initiatives. Unfortunately, the South African government does not yet have a unified policy or framework for responding to drought in agriculture. Coping and adaptation strategies would require evidence-based solutions related to agricultural water management to stimulate agriculture production during a drought period or prolonged dry spells. Currently, drought strategies are operating in 'silos' in different departments and sectors. The present set-up results in drought response to be mostly reactive instead of being proactive. Drought preparedness and resilience starts with the development of drought early warning system (DEWS) that would give enough lead time to prepare for a looming drought. In most cases, the country is caught unaware by drought events as in the case of Western Cape as the country has no dedicated DEWS (Katiyatiya *et al*., 2022; Meza *et al*., 2021; Nhamo *et al*., 2019).

Initial research results and complex support systems during the 2014/15 and 2015/16 droughts in the country have shown that there is a case for the characterisation of smallholder farmers (Ncube, 2017; Ncube & Lagardien, 2018; Ncube *et al.*, 2009). Support systems have been largely inefficient and late for many smallholder farmers, resulting in total loss of means of livelihood for some farms (Ncube, 2017). Smallholder farmers' livelihood strategies must be understood to ensure appropriate support is provided so that they can remain in production even during stressful times in order to achieve their livelihood outcomes and those of others.. In South-East Asia, the development of DEWS has resulted in the development of drought and flood-based insurance dedicated to smallholder farmers (Nhamo *et al*., 2019; Mpandeli *et al*., 2019), something that is needed in South Africa to ensure socio-economic securities.

1.3 Statement of research problem

Smallholder farmers in the Limpopo Province are mostly affected by usually the most vulnerable to droughts impacts because the province lacks effective strategies dedicated to drought and thus there are no mechanisms to cope and adapt (Cogato *et al*., 2019; Mpandeli *et al*., 2019; Nhamo *et al*., 2019; van Koppen *et al*., 2017).

Research shows that there are diverse groups of smallholder farmers whose needs are also varied (van Averbeke & Mohamed, 2006). Droughts have a significant impact on smallholder farmers' socio-economic and environmental wellbeing, but not well adequately quantified. The implications of food insecurity, crop productivity declines, livestock losses are still mostly undefined, apart from a few studies that show the percentage of households reporting these impacts (Shikwambana & Malaza, 2022; Schilling *et al*., 2020; Nhamo *et al*., 2019).

Real quantitative analyses are required to gain deeper understanding of how drought affects many socioeconomic and cultural situations, such as income, wealth, gender, and ethnicity. Drought has different effects on different landscapes and smallholder farmers, including crop loss, food shortages, and livestock loss. For instance, wealthy households might not be as affected by drought as poor households are because wealthy households have backup choices such savings to buy additional household essentials and livestock feeds, whereas poor households lack the resources to alleviate the effects of climate change impacts such as drought.

Smallholder farmers' advantages can be influenced by gender, access to and ownership of land, and local knowledge, as well as how they experience drought. Furthermore, in planning for drought risk, it may be helpful to compare drought impacts in different geographical contexts by using the spatial correlation between regions and drought impacts. Increasing drought frequency and intensity will likely affect agricultural and livestock producing regions more than remote areas as drought frequency and intensity increase.

Smallholder farmers who have struggled to adapt to climate change are the most vulnerable, and the initiatives will culminate in development of a framework for developing adaptation strategies. This is only possible after characterising smallholder farmer livelihoods and their current coping strategies are understood. A strategic approach is then developed based on the livelihoods and availability of resources. In general, a systematic approach to drought adaptation strategies of smallholder farmers has not been clearly explained in the province and the country in general, therefore there is a need to develop an optimal method for livelihood-based package to improve drought resilience of smallholder farmers in the Limpopo Province. This study therefore aims at giving new insights on the development of technologies based on farmer livelihoods and their resources endowment.

1.4 Significance of the research

This research study in the Mopani and Vhembe districts, Limpopo Province aims to study the characteristics of smallholder farmers and to come up with appropriate water management technologies and livelihood strategies for coping and adaptation to drought; and to think of a lot of choices that will be based on the farmer characteristics. The national drought management plan was developed in 2005 (DOA, 2005), but its implementation has failed in many respects. Drought impacts smallholder farmers diversely and the reaction techniques to a great extent neglect to perceive this. Smallholder farmers who are generally subsistence in nature are usually the hardest hit because they lack resources and are not insured against weather extremes resulting in total loss of their crops and livestock.

Currently, South Africa like numerous different countries in Southern Africa does not have a focused on or blended drought reaction structure/design. Existing understanding of the effects of droughts can benefit from further analysis because it can provide rigor and clarity to continuing discussions about the severity of the effects. Thoroughly analysis can help policy discussions and lead to knowledge changes on the topic, which are generally lacking in the body of research currently available. In the absence of knowledge, the idea of drought impacts is still rife with misconceptions, making it challenging to develop context-specific methods for reducing and adjusting to the effects of drought.

When designing drought adaptation strategies, such as irrigation infrastructure and water harvesting technologies to deal with future water scarcity and improve the wellbeing of smallholder farmers, an understanding of the effects of drought on smallholder farmers supported by quantitative and comparative assessments is helpful. To further understand of drought consequences, this study analysed the effects of droughts, including their size and concerns about how they are felt across socioeconomic, political, and cultural gradients. The political, institutional, and socio-economic contexts might offer frameworks for a deeper comprehension of the effects of drought, moving away from a categorical categorization of those effects.

Building farmer resilience is key methodology in readiness and building flexibility rather than the present cycle of drought-help reactions. Investing in resilience building and developing cope strategies to adapt to droughts is a priority in South Africa considering the recurrence of weather extremes. The study characterises and classifies the diverse smallholders farmers, exploring opportunities to cope and resilience building. These initiatives will also help to direct resources to the right beneficiaries in case of a disaster. New strategies will be developed with farmers to assist them in coping with future droughts.

1.5 Aim and Objectives

This aim of the study was to develop a livelihood-based package to improve drought resilience of smallholder farmers in the Limpopo Province.

The specific objectives of the study were to:

i. Assess the vulnerability of smallholder farmers to drought in the Limpopo Province (Vhembe and Mopani Districts).

ii. Characterise and classify smallholder farmers according to their livelihood strategies.

iii. Examine how smallholder farmers in the Vhembe and Mopani districts of Limpopo Province are adapting to drought conditions through coping and adaptation strategies.

iv. Identify methods of coping and adaptation for smallholder farmers in the study sites during droughts and test them in the field.

1.6 Study Area

The study focused on the Vhembe and Mopani districts of the Limpopo Province. According to the province's climate change evaluation, these two districts pose the greatest threat (Shikwambana *et al*., 2021; Nhamo *et al*., 2019; Mpandeli *et al*., 2019). The Vhembe and Mopani districts of the Limpopo are illustrated in Figure 1.1.

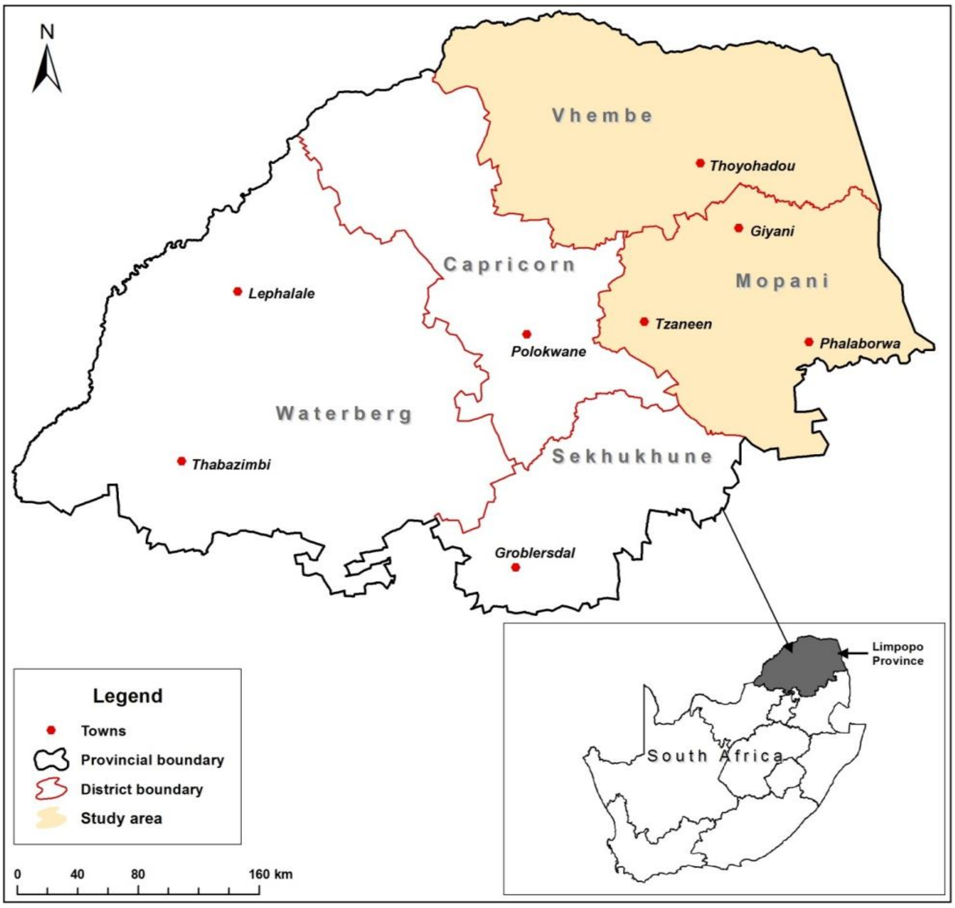


Figure 1.1: Locational map Vhembe and Mopani districts in the Limpopo Province

1.6.1 Vhembe district

The Vhembe district Municipality is located in the northern section of the province of Limpopo and has an area of roughly 25 597 km^2 (Stats SA, 2015). Through the Kruger National Park, it has shared borders with Zimbabwe and Botswana in the north-west and Mozambique in the south-east. The district's international neighbors are separated from the district by the valley of the Limpopo River. Its constituent parts are the local governments of Musina, Collins Chabane, Thulamela, and Makhado (Figure 1.2). The Thulamela municipality was selected for the study.

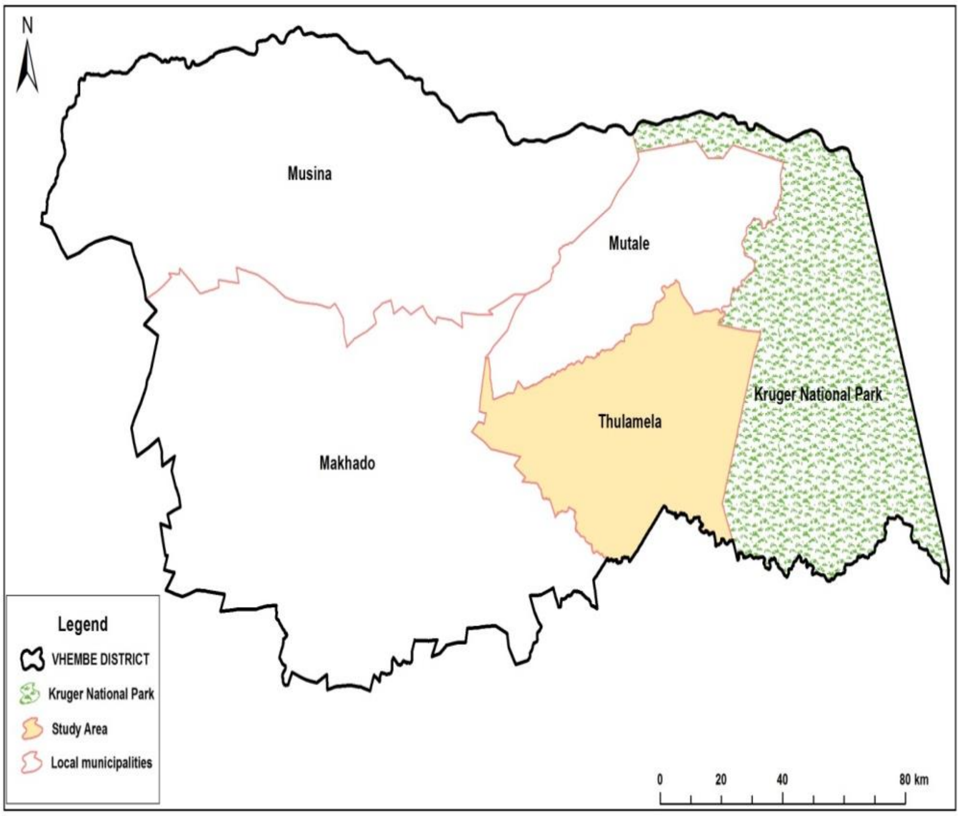


Figure 1.2: This map shows the location of Thulamela Municipality in the Vhembe district

Total population in the Vhembe district is 1 248 369 (Stats SA, 2015). While women make up the majority of the district's population (53%), 74.99% of its residents are under the age of 35 (Nthakheni, 2006). The four municipalities work with both arable and grazing operations. Compared to area utilized for cultivation, more land is used for grazing (Nthakheni, 2006). In the district, average maximum temperatures range from 24°C in the south to 37°C in the north in January, average minimum temperatures range from 8°C to 12°C in July, and average yearly temperatures range from 14°C to 29°C (Isaacs & Mohamed, 2000). The risk of extreme heat to agricultural production is greatest in January. The month of July is colder and does not see any frost. The district has summer rainfall, with average annual amounts of 300–400 mm in the north and 600–1000 mm in the south (DFED, 2004). This makes the area appropriate for a variety of agricultural products for both crops and cattle.Different types of soils with varying depths dominate the Vhembe district, although the predominant soils have depths between 450mm and 750mm, followed by those with depths of less than 450mm and patches of soil with depths greater than 750mm (DFED, 2004). Depending on the depth of the roots, these soils guide the choice of crops. The Vhembe District has a wide range of suitability for agricultural production for both crops and cattle, based on the climate and soil characteristics (Nthakheni, 2006). The Levubu Tropical Valley is located in the district, which also features places that are particularly suited for tropical and subtropical fruits. Along river valleys, irrigation systems are used to grow vegetables, with the Nwanedi Valley being particularly well-known for its tomato output (LDA, 2005). As a result, there has been significant investment in infrastructure for producing and adding value to fruits, vegetables, and poultry (DEDET, 2006).

1.6.2 Mopani district

Because of the region's profusion of nutrient-rich mopani worms, the district was given the name Mopani (IDP, 2012). The district is made up of the Greater Tzaneen, Greater Giyani, Letaba, Maruleng, and Ba-Phalaborwa municipalities (Figure 1.3). The district has an around 1 437 734 ha total land area (IDP, 2012). The Greater Tzaneen and Greater Giyani local municipalities were the only two of the five municipalities to be evaluated for this project..

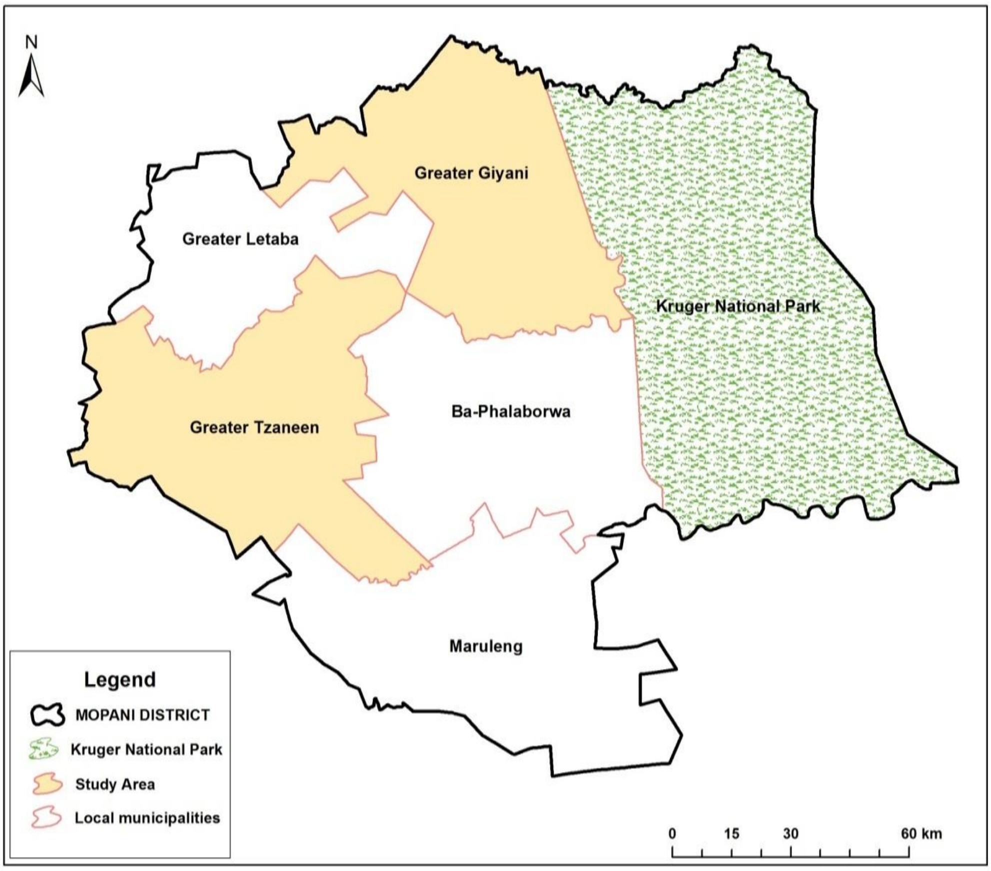


Figure 1.3: This map shows the Greater Tzaneen and Greater Giyani municipalities in the Mopani district

Low rainfall of roughly 700mm annually, much lower in low lying portions of Giyani and Ba-Phalaborwa municipalities, is a defining feature of the Mopani district. The Letaba River basin serves as the Mopani district's primary source of surface water. In the district, there are a number of other rivers, including Groot Letaba, Politsi, Debengeni, Thabina, and Letsitele (DEDET, 2006). There are more than 20 big dams, nine of which are used for domestic uses and the others for irrigation (LDA, 2005). Borehole water are use to supplement surface water.

In the district, average maximum temperatures range from 21 to 37 degrees Celsius in January, average minimum temperatures range from 5 to 12 degrees Celsius in July, and there are 13 to 27 degrees Celsius on average throughout the year (LDA, 2005). Since January is the hottest month of the year, excessive heat is a problem. Since July is often cooler than other months, the district does not see a lot of frost problems. While the area at the foot and on the escarpment receive 600-800mm and 800-1000mm correspondingly in terms of yearly rainfall, the district's eastward side of the Drakensberg escarpment receives an average of 400-500mm (LDA, 2005). Due to them, the district can accommodate a variety of agricultural products, including both crops and cattle..

The soils in the area range in depth from less than 450mm to more than 750mm (DFED, 2004). Soils in the southern and central parts of the district are often less than 450mm deep, whilst those on the western side are typically more than 750mm deep. In the northern part of the district, there are sections of soil with a depth of between 450mm and 750mm (DFED, 2004). Rivers run across the area, some of which are utilized for irrigation. Water use for irrigation is often limited in the Giyani region due to water scarcity. The district has a wide range of suitability for crop and livestock production based on soil capabilities(LDA, 2005).

Citrus, mangoes, vegetables, animals, poultry, and other crops are all examples of agricultural products. Since 1996, mining has dominated the economy and accounted for 31% of GDP in 2006 (IDP, 2012). Due to its proximity to the Kruger National Park, trade, tourism, and finance are all active industries in the region. One of the main economic sectors that predominates in the municipalities of Tzaneen, Letaba, and Maruleng is agriculture. The Tzaneen, Letaba, and other regions of Ba-Phalaborwa produce roughly 10,000 ha of citrus fruits, which are marketed on the export market (DEDET, 2006).

1.7 Delineation of the study

The study was confined to the Greater Giyani, Greater Tzaneen and Thulamela Municipalities of Vhembe and Mopani District and to the exclusion of areas beyond this place. The study investigated the impacts of rainfall and temperature changes on smallholder agriculture, drought conditions in the Mopani and Vhembe districts for the past five decades, resilience and adaptive capacity of smallholder farmers to drought, and then classify the smallholder farmers according to livelihoods coping strategies. With the help of extension officers in the Limpopo Province, rural farming areas dominated by smallholder farmers facing drought challenges on a regular basis were selected. These centres include: Berlyn, Naphuno, Mamitwa, Tzaneen, Hlaniki, Guwela, Muhlava Welemu, Labani, and Khalavha.

1.8 The thesis overview

There are eight chapters in this study.

1. Chapter One is an introductory chapter that has outlined the background, provide a rationale for the study, list the key research objectives, and summarised the data analysis adopted.

2. Chapter Two presents a literature review of smallholder farmers Global, Regional, National, Limpopo Province, and Local Municipalities, climate change, livelihoods, coping and adapting strategies to Local Municipalities in the Limpopo Province, South Africa.

3. Chapter Three explores the methodology that was used to carry out the research. It describes in detail all the processes and procedures followed to come up with detailed results. Statistical methods used are also detailed in this chapter.

4. Chapter Four explores the impacts of rainfall and temperature changes on smallholder agriculture in the Limpopo Province. This chapter assesses the trends in the monthly, seasonal, and annual rainfall, maximum and minimum temperatures, as well as the Climatic Moisture Index (CMI) in the Mopani and Vhembe districts of the Limpopo Province over a period of five decades.

5. Chapter Five assesed the adaptive capacity of smallholder farmers to climate change in the Mopani and Vhembe districts of the Limpopo Province using observed data.

6. Chapter Six explored the resilience and adaptive capacity of smallholder farmers to drought in the Vhembe and Mopani districts of the Limpopo Province. This chapter presents and discusses the socioeconomic profile of smallholder farmers through an examination of household demographics, asset ownership, and source of income.

7. Chapter Seven presents the classification smallholder farmers according to their livelihood strategies in the Limpopo Province. The point was to distinguish homogenous farming households and their ability to naturally choose different livelihood strategies to acquire better living standards.

8. Chapter Eight first summarizes the main research findings, and then select solutions for smallholder farmers in Limpopo to cope and adapt during droughts.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review, starting with a background on drought, definitions, determination, and vulnerability of smallholder farmers. It then details smallholder farmer livelihood characteristics and strategies. Finally, it discusses coping and adaptation strategies for agricultural water use adopted by smallholder farmers during drought periods. This chapter also discusses the sustainable livelihood framework on which the classification will be based on. A was also discussed in details. The conceptual framework is also included in this chapter. The conclusion forms the final part of the chapter.

2.2 Background

The Southern African Development Community (SADC) area is known to be one of the places in Africa that are prone to experiencing regular instances of drought, and extreme droughts have been seen in this region for more than a century (Nembilwi *et al*., 2021; Olaleye, 2010). The Limpopo River Basin is not an exception; significant agricultural seasons were affected by severe drought conditions throughout the following years: 1982–1983, 1987–1988, 1991–1992, 1994–1995, 2002–2003, 2008–2009, and 2015–2016 (Nembilwi *et al*., 2021; BFAP, 2016; Olaleye, 2010). When compared to earlier significant droughts, the ones that occurred in 1982–1983 and 1991–1992 were the absolute worst (Vogel *et al*., 2000). On the other hand, the nation was struck by one of the worst droughts in the last century during the 2015–2016 growing season, which had a significant negative impact on agricultural productivity (Nembilwi *et al*., 2021; BFAP, 2016; Olaleye, 2010). Since 1990, the occurrence of droughts has been more frequent, which has a detrimental influence on the economy overall. South Africa has been experiencing droughts around once every three years, the most recent of which being the drought that lasted from 2015 to 2016 and was felt over the entirety of sub-Saharan Africa (Nhamo *et al*., 2019). This drought lasted until 2018 across the Cape provinces, with the Western Cape Province seeing the most severe effects.

According to Austin (2008), the phenomenon known as El Nino Southern Oscillation (ENSO) is one of the primary factors that contribute to drought. ENSO is an acronym that stands for El Nino Southern Oscillation. This interaction between the atmosphere and the ocean in the tropical Pacific region causes a somewhat periodic variation in sea surface temperatures that can range from below normal to above normal as well as dry to wet conditions over the course of a few years (Nooni *et al*., 2021; Holloway *et al*., 2012; Austin, 2008). Conditions will be warm and dry in that region as a result of an El Nino event because clouds that normally form over the southern half of the subcontinent will go out to sea during an El Nino event, reducing the number of clouds that normally form over that region (Austin, 2008). In contrast to El Nino, which is associated with below-average precipitation, a La Nia event is associated with above-average precipitation, even though it does not always produce floods (Olaleye, 2010; Nicholson & Selato, 2000). However, Wright *et al*. (2015) & Vogel *et al*. (2000) clarified that not all drought occurrences in South Africa can be characterized by the ENSO, but that it can be tied to ordinary climatic variability owing to climate change. These findings were published in the journal Geophysical Research Letters (Nooni *et al*., 2021). The recurrence of drought continues to have a negative impact on the lives of disadvantaged smallholder farmers in the province of Limpopo, who lack the resources to adapt.

Almost 60% of all of South Africa's fruit, vegetables, maize, wheat, and cotton are produced in the province of Limpopo (LEDET, 2006). Another industry that makes a significant contribution to the province's economy is livestock farming. It is estimated that 33% of households in Limpopo are agricultural households, with a large rural population that depends on agriculture as a means of livelihood and food security (Nthakheni, 2006; LEDET, 2006; LDA 2004). This is due to the fact that agriculture is the primary source of income for a large portion of the rural population in Limpopo. It is anticipated that when temperatures continue to rise and there is a corresponding increase in the unpredictability of rainfall, there will be a shift in the parts of the province that are ideal for some crops, such as maize, while other crops, such as lemons, would no longer be feasible. Temperature increases will not only result in the requirement for greater irrigation and cooling, but they may also have negative effects on cattle, which will have an adverse effect on profits (IDP, 2012). It has been determined that the province of Limpopo in South Africa is the most susceptible to the effects of climate change on agriculture. This is mostly because to the high number of smallholder farmers in the province (Nembilwi *et al*., 2021; Sinyolo *et al*., 2014; Khulisa, 2016).

There is no one description that can be applied universally to smallholder farmers; instead, the criteria that define them vary from nation to country and area to region. There is no agreed-upon description of what exactly "smallholder farmers" are in South

Africa. In order to characterize and categorize the farmers, it is necessary to take into account the other factors that are prevalent in their population. It's possible that the farmer characterization and livelihoods strategy might be one of these approaches. The reduction in output that results from drought is one of the most significant effects it has on the agriculture sector. Farmers in South Africa are consistently in the most precarious position whenever there is a drought since they are the first people to feel the wrath of the natural disaster. A state of disaster may only be proclaimed in accordance with the Disaster Management Act number 57 of 2002 when the people who are afflicted do not have the resource ability to deal with drought (DMA, 2002).

2.3 Drought

2.3.1 Definition

To better comprehend the different ideas related to drought, Sun (2009) stressed the importance of drought definition that give a reasonable comprehension of determination. However, there is no standard definition partially due to different perspective by various users. Drought definitions can be portrayed as either conceptual or operational (Das, 2012; Wilhite & Glantz, 1987) and the term is not easily defined and often depends on who you are addressing to i.e.:

- SAWS (2016), hinted out that any amount of precipitation less than 75% of the mean annual precipitation constitutes a drought.
- Palmer (1965), explained drought ass the actual rainfall that is less than the rainfall which is climatically appropriate for the existing conditions at the point which the honest to goodness precipitation isn't as much as the precipitation which is climatically legitimate for the present conditions.
- Beran & Rodier (1985), defined drought as a decrease of water availability over a particular period and area.
- IPCC (2007), defined drought as water shortage for some activities resulting from a prolonged insufficient rainfall.
- Mekuria *et al.* (2021), defined drought as an incessantly happening climatic phenomenon mostly related to the reduction of precipitation.

These definitions help to comprehend the meaning of drought, and can be genuinely unclear, does not give quantitative responses to when, how and what extent drought can be. Operational definitions also give the level of take-off from the normal precipitation over a specific period (Das, 2012), and these definitions determine the qualities and limits that characterize the beginning, seriousness, advancement and the finish of a drought occasion (Wilhite, 2000). In South Africa, a routinely used operational banner for drought caution in a couple of dry season checking and help designs is that given by the South African Weather Service (SAWS, 2016), communicating that any proportion of precipitation under 75% of the mean yearly precipitation establishes a drought.

Types of drought has numerous characteristics that generally begins with an inadequacy of precipitation, influencing soil moisture, stream streams, groundwater, biological systems and individuals depending on its duration and intensity (Smakhtin & Hughes, 2004). In light of these biophysical, socio-economic and socio-political attributing factors, Vogel & van Zyl (2016) illuminated drought as a 'wicked issue and test'. In this way, drought was grouped into four characterizations viz. meteorological, agricultural, hydrological and socio-economic.

2.3.1 Meteorological drought

Due to an inadequate amount of precipitation, a meteorological dry spell is distinguished solely by the degree of dryness as well as the duration of the dry period of time (Smakhtin & Hughes, 2004; Wilhite, 2000; Lourens, 1995). This form of drought is based on the physical characteristics of dry season, such as the take-off of precipitation from ordinary, rather than on the impacts that are associated with it. For example, the take-off of precipitation from normal. Because of the wide variety of environmental factors that might lead to precipitation deficiencies in different parts of the world, the answer to this question is dependent on the normal weather patterns that prevail in the area that is being investigated (Abubakar *et al*., 2020; Sun, 2009). In this approach, it is essential to modify a definition that was developed in one region of the world before using it in another region (Mniki, 2009).

2.3.2 Agricultural drought

Drought is a ordinary habitual match that influences the livelihoods of thousands and thousands of human beings round the world, and in particular the 200 million human beings dwelling in southern Africa. Climate variability, which consists of erratic and unpredictable seasonal rainfall, floods and cyclones, contributes to the hazard of farming throughout most of southern Africa, however specifically in marginal rainfed agricultural areas that are characterised by using low and erratic precipitation.

A dry spell can occur under specific circumstances when the water content of the soil falls below a particular threshold. This can result in decreased agricultural yields as well as decreased animal supply (Measho *et al*., 2019; Bordi & Sutera, 2007). It is characterized by precipitation shortages and high evapotranspiration, frequently prompting soil water deficiencies, and consequently influencing farming procedures (Das, 2012). Taking into consideration the fact that plant water needs are dependent on the crop variety, environment, and stage of plant growth, in this manner; agricultural drought does not just depend on the amount of precipitation received, but also on the planning and duration of the drought (Measho *et al*., 2019; Fraisse *et al*., 2011).

2.3.3 Hydrological drought

A hydrological dry spell is characterized by abnormally low levels of surface water bodies (lakes, dams, streams, and rivers), as well as groundwater (Fraisse *et al*., 2011). The length of time that passes between occurrences of precipitation in the hydrological framework of a number of nations is one of the causes of a lengthy meteorological or agricultural drought. (Sun, 2009). This kind of drought could be made worse by the rate of water loss that occurs as a result of factors such as evapotranspiration and social activities that include extracting water for water systems or residential use, which could lead to a reduction in stream flow levels and release from reservoirs. This sort of drought could also be caused by a combination of factors (Kusangaya *et al*., 2013). Dam storage levels across the KZN province dropped to less than 50 percent during the hydrological year 2014/2015 as a direct result of the prolonged drought (Ndlovu & Demlie, 2020).

2.3.4 Socioeconomic drought

Due to the fact that food grains and animal grazing are dependent on precipitation, a socioeconomic drought arises when there is an inadequate amount of precipitation and it begins to have an impact on human wellness, wealth, and personal happiness (Sun, 2009). It is a reflection of the interrelationship between climatic, agricultural, and water-related drought and the vulnerability of human beings (Wilhite & Buchanan-Smith, 2005), and its occurrence can increase due to a change in the frequency of other types of drought, a shift in social water vulnerability deficiencies, or both (Wilhite & Buchanan-Smith, 2005). Increased demand for certain monetary goods as a result of population expansion can potentially magnify the negative effects of socioeconomic drought (Dlamini, 2013). The past several years have been marked by a string of droughts in South Africa, which has led to a reduction in the amount of water that can be stored in reservoirs and has had an effect on a wide range of economic activities (Ndlovu & Demlie, 2020).

2.4 Drought Indices

Indicators of drought are the most common type of measurement utilized for establishing the beginning, severity, and length of a drought, as well as its geographical and temporal aspects. (Wu *et al*., 2004). They have been developed over the course of time in order to detect and display the occurrence and effects of droughts. However, because different users have different conceptions of what constitutes a drought, the standards for predicting the severity of a drought cannot be captured by a single index (Heim, 2002; Song *et al*., 2014). The following is a description of some of the indices:

2.4.1 Standardized Precipitation Index (SPI)

McKee *et al*. (1993) built up the Standardized Precipitation Index (SPI) in view of the likelihood of precipitation for 3, 6, 12, 24, and 48-month time scales. SPI calculation is based on precipitation data fitted to likelihood dispersion afterward that is transformed to follow a normal distribution (McKee *et al*., 1993). This index utilizes an order framework whereby wet and drought conditions are shown by positive and negative values respectively (Sonmez *et al*., 2005). The SPI is restricted to long haul regular precipitation datasets, and utilization of little verifiable records may prompt dishonestly expansive positive or negative SPI values (Hayes *et al*., 1999). Wet and dry seasons can be monitored equally due to its uniform character (Uwimbabazi *et al*., 2021; Das, 2012). Because it takes less input data and the computations are flexible, this index recognizes more uses of monitoring drought conditions throughout the world than other drought indices (Smakhtin & Hughes, 2004).

2.4.2 Standardized Precipitation Evapotranspiration Index (SPEI)

Standardized Precipitation Evapotranspiration Index (SPEI) the Standardized Precipitation Evapotranspiration Index (SPEI), which is the modified SPI was developed by Vicente Serrano *et al*. (2010) taking into account both precipitation and evapotranspiration (Uwimbabazi *et al*., 2021; Vicente-Serrano *et al*., 2015). The SPEI uses the same classification system as that of the SPI, with evapotranspiration incorporated and due to the inclusion of temperature, the main advantage of this index above other indices is its ability to combine the effects of temperature variability and evapotranspiration in assessing drought risk (Nembilwi *et al*., 2021, Adisa *et al*., 2020; Potop *et al*., 2012; Vicente-Serrano *et al*., 2010). However, one significant drawback of this index is in the computation of evapo - transpiration, where a lack of trustworthy data for all factors may result in mistakes (Vicente-Serrano *et al*., 2010). Vicente-Serrano *et al*. (2015) included two additional techniques for estimating evapotranspiration in addition to the Thornthwaite approach to lessen the susceptibility to inaccuracy.

2.4.3 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) The most prominent vegetation index used for monitoring drought is the Normalized Difference Vegetation Index (NDVI), developed by Tucker (1979) which monitors vegetation reflectance in the invisible and infrared range of the electromagnetic spectrum. According to Nooni *et al*. (2021), the formulation of NDVI is given as the ratio of the difference between near-infrared and red wavelengths to their sum. The mean of NDVI is utilized for overall greenness, the maximum of NDVI for peak greenness, NDVI intensity for real-time greenness, and multi-temporal NDVI for vegetation monitoring (Padhee, 2013). A high NDVI value indicates dense vegetation cover, permeable soil, and substantial soil humidity (Buma & Lee, 2019; Eden, 2012), while a low NDVI value indicates little or no vegetation, moderate impermeable soil, and minimum soil moisture (Buma & Lee, 2019; Eden, 2012; Padhee, 2013). This index is not plant specific since it takes into account the total vegetated area, nevertheless it is one of the most often used indexes for drought monitoring based on remote sensing data (Buma & Lee, 2019; Padhee, 2013; Eden, 2012; Legesse, 2010).

2.4.4 Crop Specific Drought Index (CSDI)

Meyer *et al*. (1993) developed the Crop Specific Drought Index (CSDI) based on assessing agricultural drought for specific crops, specific soils and the growth stage during which the drought stress occurs. The index was initially developed for maize and then extended to soybeans, then wheat and sorghum successively (Wu *et al*., 2004). It is based on computing actual evapotranspiration to potential evapotranspiration (Jordaan, 2012), and calculates the degree of drought stress to a specific crop of interest using daily meteorological data, soil, and information on the growth stage of the specific crop of interest (Meyer *et al*., 1993). Therefore, it can be used as a proxy for predicting crop yield and has advantages over other drought indices such as Palmer Drought Severity Index (PDSI) and Crop Moisture Index (CMI) (Jordaan, 2012; Wu *et al*., 2004).

2.4.5 Crop Moisture Index (CMI)

Palmer (1968) later designed the Crop Moisture Index (CMI) based on similar formulations of the PDSI. Following the PDSI shortfall of not capturing potential agricultural droughts, the CMI was developed to evaluate meteorological dry and wet spells for short-term (weekly) periods that uses weekly precipitation, temperature and a CMI value of the previous week as inputs (Jordaan, 2012). The resultant CMI is the sum of the evapotranspiration anomaly represented by slight positive to negative values, whereas water surplus is reflected by positive values (Das, 2012). This index was designed for monitoring short-term drought conditions affecting crop development (Hayes *et al*., 1999,)however it cannot be used to monitor long-term droughts as it captures near-normal precipitation with drought as adequate, thus underestimating prolonged drought conditions (Buma & Lee, 2019; Das, 2012). Jordaan (2012) stated that the CMI's application is therefore limited to the growing season of a specific crop and cannot be used to monitor droughts outside a specific growing season (longer-term droughts).

2.5 Drought vulnerability

While there are different definitions for vulnerability, since is bound by setting, a specific significance of vulnerability may not be shielded. The Collins English Dictionary, nonetheless, characterizes vulnerability as, *inter alia*, the capacity to be physically or authentically harmed or hurt (Kelly & Adger, 2000). Scientists from different fields of specialization have been conceptualizing vulnerability differently in light of their objectives and the rationalities used inside their individual settings. These qualifications confine the probability of having a for the most part recognized importance of vulnerability. Regardless, the learning of the current sensible and methodological technologies can affect the choice of one of the procedures, or a mix of existing systems, in dismembering vulnerability for a specific district of premium (Abiodun *et al*., 2017; Deressa *et al*., 2008).

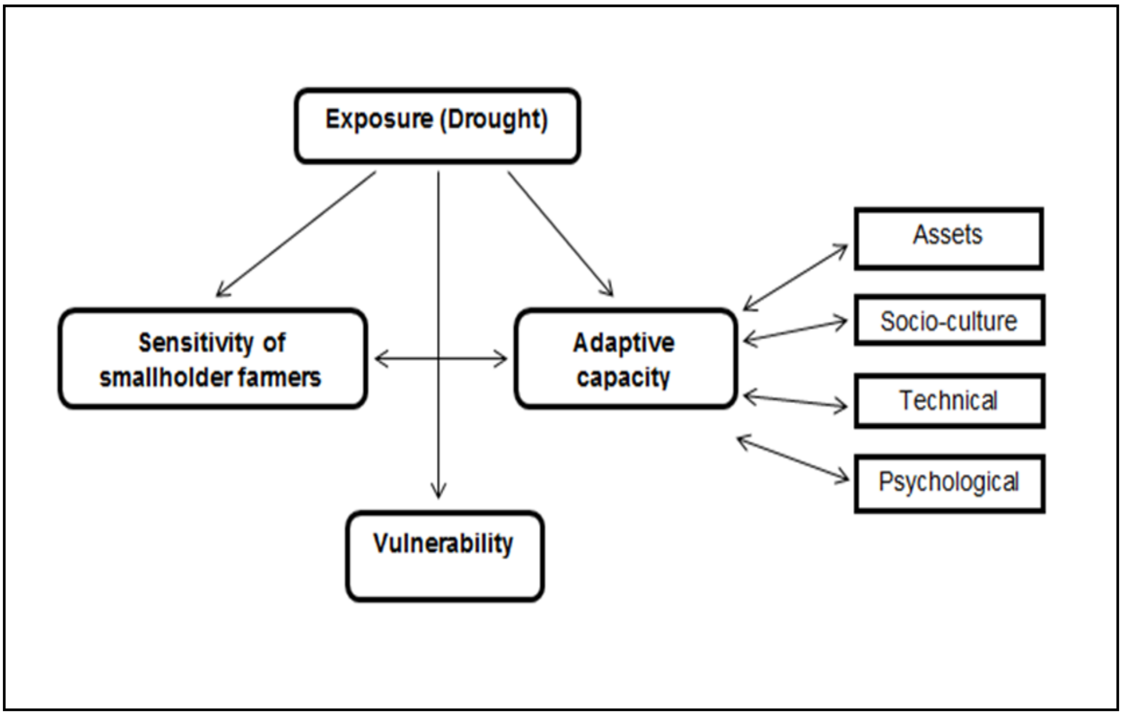
The logical utilization of vulnerability has its hidden establishments in geography and common dangers research about, yet this term is as of now a central thought in a collection of other research context, for example, horticulture, biology, public health, destitution and advancement, secure livelihoods and starvation, climate effects and adaptation (Ngcamu & Chari, 2020; Fussel & Klein, 2002). Vulnerability is characterized as the level of hardship in a given part in peril and includes a game plan of such segments that result from the event of a characteristic wonder in a given enormity and by and large communicated on a scale from 0 to 1 (Buckle *et al*., 2000). As indicated by IPCC (2001), vulnerability goes up against both negative and positive characteristics of a given population. At the end of the day, vulnerability has both positive and negative measurements. The positive measurement is identified with vulnerability's relationship to the procedure of adaption, which, for this situation, gives a framework to improving the point of confinement of people to respond to weight. At the end of the day, adaptation is encouraged by decreasing vulnerability (Ngcamu & Chari, 2020; Zeroual *et al*., 2019; Nashwan *et al*., 2019).

Another legitimate of vulnerability is the limit of a man or assembling to imagine, restrict, adjust to, and recuperate from the effect of characteristic or man-made perils (Blaikie *et al*., 1994). One of the benefits of this definition is that it recognizes vulnerable groups and areas in a community. On one hand, this data is essential for dry season administration strategy producers who regularly need to organize constrained assets when planning mediations to decrease vulnerability. The assessment of who is vulnerable and why is one of the principle parts of dry season alleviation and arranging (Wilhelmi & Wilhite, 2002).

As indicated by Adger (1999), social vulnerability is the exposure of groups or people to worry because of social and ecological change, worry in this setting alluding to sudden change and the disturbance of employments. This definition stresses the social measurements of vulnerability differentiates the biophysical way to deal with drought vulnerability that for the most part considers physical misfortunes like yield, pay and so forth, overlooking numerous parts of the versatile limit of the social measurements. Also, drought vulnerability can differ for diverse individuals and nations. As per Brooks *et al*. (2005), take note of that factors that make a rustic network in creating nation vulnerable against drought could be unique in relation to those of a well off industrialized country. In fact, even in a given structure, vulnerability is likely not going to be the equivalent for drought-affected areas in contrast with less influenced zones (Smit & Wandel, 2006). Downing & Bakker (2000) conveyed that dangerous climate contrasts from conventional climate by its capacity to do hurt, and not by it are physical or genuine properties.

Vulnerable groups cannot provide for their essential needs on account of unfavourable economic and wellbeing conditions and mental status of those in danger (Ngcamu & Chari, 2020; Jazayeri, 1996). Consequently, the distinguishing proof of vulnerable groups can go about as an area point to both appreciate and address the methodology that reason and exacerbate vulnerability (Brooks *et al*., 2005). Strangely, vulnerability differs starting with one district then onto the next because of different economic, political, social, and recorded impacts (Mekuria *et al.*, 2021). Accordingly, some groups endure more than other groups in the network. This distinction in vulnerability is because of various individual, socio-economic, biophysical qualities, and access to infrastructural and access to data sources (Brant, 2007; Wilhelmi & Wilhite, 2002; Downing & Bakker, 2000).

The idea of vulnerability has additionally been concentrated by sociologists, for example, Gillard & Paton (1999) & Carver *et al*. (1989) who demonstrated that vulnerability to calamity and stress speaks to a mind boggling web of religious, social, social and mental variables (Carver *et al*., 1989; Gillard & Paton, 1999). For example, there are strong relationships between religion and other factors likely to affect vulnerability, including education, socio-economic statuses and housing location and



quality (Mekuria *et al*., 2021). In the context of drought, vulnerability has different dimensions (IPCC, 2001), with the drought intensity (exposure) farmers are faced with as a key issue (Figure 2.1). Farmers' adaptive capacity is also influential in how people cope with drought. Moreover, their sensitivity deals with how farmers are affected by drought. Overall, farmers' vulnerability to drought is affected by economic, socio-culture, psychological, technical and infrastructural factors.

Figure 2.1: Conceptualizing vulnerability in the context of drought

(Adapted: Zarafshani *et al*., 2016)

South Africa has struggled to effectively plan for and respond to the effects of drought in agricultural systems. The reasons behind this include historical in nature, as well as connected to planning and the socioeconomic context. Before examining the farming coping and adaptation tactics, it is necessary to provide a brief history of drought in South Africa. Improving the resilience of food production systems is critical to feeding a rising population, and smallholder farming communities' livelihood strategies will need to be reinforced to sustain food security and livelihoods in these already marginal locations. As a result, climate change must be tackled as part of the entire development agenda.

2.6 Classifications of smallholder farmers according to livelihoods strategies

South African agribusiness has a twofold agrarian structure including both substantial scale business white cultivating and little scale asset compelled black cultivating (Mthembu, 2013; van Averbeke, 2008; Kirsten & van Zyl, 1998). The terms 'small-scale farmer' and 'smallholder' are ordinarily utilized when alluding to African farmers, on the grounds that the lion's share of African farmers in this nation work undertakings that are little in estimate, customary practices, and high neediness levels caused by the low returns related with lacking business sector interest in respect to those of White farmers (van Averbeke, 2008; Fanadzo *et al*., 2010).

The smallholder part is for the most part situated in the previous homeland regions on little landholdings and is found in an extensive variety of areas in South Africa from profound provincial territories to townships, urban communities and on commercial farms (Piennar, 2013; Lahiff & Cousins, 2005). Machethe *et al*. (2004) characterized smallholder farmers in view of past racial contrasts and are subsistence farmers who chiefly deliver for home utilization with low, if any attractive excess. Aliber *et al*. (2009) accepted a wide meaning of rural smallholders in South Africa, including farmers who work freely, cultivate in gatherings, subsistence farmers, and the market orientated whose intention is predominantly business. Ortmann & King (2010) characterize them as farmers with restricted access to variables of creation, credit, data, markets and are regularly compelled by insufficient property rights and high exchange costs, the family work utilize is predominant on the ranches, and are looked with absence of fundamental assets, for example, financial, social and human capital.

In this manner, there are two classes of smallholders that can be recognized utilizing this more extensive definition, those cultivating is fundamentally subsistence and the commercially situated smallholders. The commercially agricultural segment works on a substantial scale, supplied with common assets and very much created and gifted and semi-talented work, more bought input and refined innovations obtaining, and for the most part made out of white individuals. The second division incorporates the small scale subsistence agriculture dominatingly possessed by asset poor dark People (Black means non-white and incorporates Africans, Colored and Asians/Indians) (Adger *et al*., 2004).

These smallholder farmers are related with the land change program and are essentially black smallholders who are required to create more for the market yet are most likely not doing as such (van Averbeke *et al*., 2011). National Development Plan (2011) recognizes the significance of the farming in building up the rural economies and producing work through the making of no less than one million new occupations. Because of constrained access to credit, smallholders can scarcely embrace new innovations which may require a mix of obtained contributions for expanded efficiency (Essa & Nieuwoudt, 2003). Low efficiency limits them in taking an interest in the neighbourhood, national and global markets (Ifeanyi-Obi *et al*., 2011).

Furthermore, Kirsten & van Zyl (1998) argued that it is difficult to know who to focus on when analyzing the viability of small scale farms. This ambiguity is exacerbated by who agreed that "it is more tougher to figure out who is indicated when reference is made to small-scale farmers". They also alluded to the difficulty in describing and categorizing the smallholder farmer as a methodological challenge. These definitions show that there is no one name for smallholder farmers in South Africa. Other factors that exist among farmers must be considered in order to characterize and classify them. One such way may be the farmer characterization and livelihoods strategy.

Ellis (1998) defines livelihood diversification as the process by which families acquire a diverse set of workouts and social aid capacities in their struggle for survival and with the specific objective of improving their ways of life. Chambers & Conway (1991) define a livelihood as techniques of earning a living. They also use the World Commission on Environment and Development's definition of "livelihood" as "adequate stocks and streams of sustenance and money to address basic concerns". Thus, livelihood plans incorporate household assets into activities that provide a variety of outputs aimed at meeting people's current consumption requirements while also investing in assets and activities for the future (Dorward *et al*., 2009).

The Sustainable Livelihood framework recognizes the gigantic assorted variety of livelihood frameworks inside rural networks (Mapedza *et al*., 2008). Rural households vary by the mix of advantages they approach, the financial conditions in which they take their choices and the arrangement of exercises they perform, specifically editing, domesticated animals and normal asset utilize exercises (Mapedza *et al*., 2008). Family typology seems, by all accounts, to be a fitting instrument to depict this assorted variety and break down its deciding components (Piennar, 2013).

The livelihood practices of smallholder farmers are especially important to us. Cousins (2010) define smallholders as "small-scale agriculturists who use cultivate deliver for home use to some extent, and use family work inside the cultivating activity to some extent, yet for whom cultivating contributes an extremely significant measure of money pay through showcasing of homestead create." Smallholders are forced to seek a range of livelihood alternatives in order to make a living since they differ in a number of ways. Dorward *et al*. (2009) classified the livelihood options of cattle producers in Mexico and Bolivia into three major categories: hanging in, stepping up, and stepping down. Hanging-on homes are ones where resources are retained and exercises are carried out to maintain livelihood levels due to unfavorable financial situations. Stepping-up families engage in activities and invest in assets to expand their operations, boosting production and income and enhancing their quality of life. Stepping-down households participate in current activities to accumulate resources, which eventually allows them to diversify their operations into new companies that become important.

Scoones *et al*. (2012) used this method to gain a comprehensive insight of the lives of smallholder farmers in Zimbabwe who benefitted from the Zimbabwean government's massive land reform project. In addition to the preceding groups, 'dropping out' was described as poor households that were not successful in agriculture and abandoned their plots. These varied strategies are linked to distinct rural communities defined by asset endowments as well as socioeconomic and political advantages. These classes included the following:

- Asset poor farmers
- Chronically poor farmers
- Part-time farmers
- Semi-commercial farmers

These proposed livelihood system arrangements are helpful for their unequivocal acknowledgment of the dynamic desires of individuals, and of separation by individuals undertaking an assortment of exercises as they blend their procedures and exercises in quest for their goals (Dorward *et al*., 2009). Scoones *et al*. (2012) warn that no typology is ever definitive, and that there are always variations and an obscuring. Nevertheless, this livelihood strategy classification was used in this study to understand the production and livelihood strategies that smallholder farmers pursue in obtaining a living.

Classification conspires inside agribusiness have been generally used to portray and break down decent variety in horticultural endeavours and includes building up an arrangement of formal classifications into which a specific field of information is divided (Piennar, 2013). Piennar, (2013), characterized a typology as a specific kind of thorough classification in which a field of information is partitioned up into classes that are altogether characterized by a similar arrangement of criteria, and that are fundamentally unrelated, and as indicated by Tefera *et al*. (2004) a typology is characterized as a quantitative or subjective method that classifies families or people into homogenous gatherings, which confront comparative imperatives and motivations and are impacted by outer factors correspondingly. Piennar (2013), featured that decent variety inside the rustic condition shows itself in different reactions and the utilization of ranch typologies is a helpful method for portraying this assorted variety and can be accomplished by determining the auxiliary qualities of various homestead composes, where each compose or gathering is altogether not quite the same as the other in connection to a predetermined standard (Laurent *et al*., 1999; van der Ploeg *et al*., 2009). In this manner, the pertinence of any homestead typology will depend intensely on its capacity to catch the decent variety of cultivating frameworks through boosting the homogeneity inside gatherings and the heterogeneity between gatherings (Piennar, 2013).

Smallholder agriculture contributes to food security as one of the livelihoods strategies of the rural population. It should be noted that since most people in the rural areas are dependent on agriculture other options are available as well to supplement its role in ensuring food security but agriculture, however, remains the centre focus amongst these livelihood strategies (Toringepi, 2016; Bembridge, 2000; Ncube, 2014), classified small-scale irrigation schemes in South Africa in terms of the following five types:

- Top down bureaucratically managed schemes
- Joint venture
- Community schemes
- State or corporation financed schemes
- Large estate schemes

Various researchers have used the following typologies to categorise smallholder farmers:

- Farmers are classified as minor commodity producers, subsistence food producers, or commercial vegetable growers, according to Tapela (2008).

- Cousins (2010) characterized supplemental food producers as allotment-holding wage workers, worker-peasants, small-scale capitalist farmers, and capitalists whose principal source of income is not farming. He focused on farm workers. The primary factors he considered were the extent to which agriculture contributes to social or extended proliferation, as well as the amount of engaged labor utilised in the agricultural business.

- According to Machethe *et al.* (2004), there are two types of smallholder farmers: resource poor farmers, who have farming and non-farming livelihood activities but whose total assets and annual income are insufficient to classify them as 'poor,' and middle income farmers, whose primary source of revenue is farming and whose assets and annual salary are worth more than that of poor households and thus are relatively significant.

- Smallholder farmers on irrigation systems were divided into four groups by Denison & Manona (2007): smallholders, business farmers, food producers, and equity laborers. Smallholders often have smaller plots, produce a variety of crops, use lower-risk practices, use less water, and are usually on flood and smaller schemes. The 'business farmers' have larger plots, need more work in land leasing, are more externally oriented with a monetary emphasis, and agriculture is their principal source of income. The 'food producers' have large food gardens and generally grow crops for their own consumption. 'Equity workers' frequently use commercial partnership agreements, joint enterprises, and share cropping. Their main advantage is basic employment, especially in programs with high running costs.

Given the difficulties of cultivating as a result of environmental change, arrive corruption, and water scarcity effects, as well as changing social and social factors that are changing provincial territories in new ways, many rural households accept various wage creating systems in order to build sustainable livelihoods. In the case of Limpopo Province, smallholder farmers dominate the province's economy, and the province is renowned as South Africa's bread basket (Cai *et al*., 2016). Agriculture has provided jobs in Limpopo Province, contributing significantly to food security and poverty alleviation (Sinyolo *et al*., 2014; Khulisa, 2016). South Africa has made significant investments in smallholder farms since the country's inception, with the ultimate objective of assuring family food security and relieving poverty (Sinyolo *et al*., 2014). Regardless, there is no classification of smallholder farmers' livelihoods in Limpopo Province. Cousins (2010) contends that the literature fails to define smallholder farming since the many types of smallholder farmers are not taken into account.

2.7 Smallholder famers coping and adaptation strategies to drought

Analysts take note of that the decision of adapting techniques and how individuals react to a distressing circumstance relies upon personal attributes. For instance, Knutson *et al*. (1998) contend that most drought circumstances that prompt pressure that can result in an assortment of reactions. These reactions are classified into problem-focused and emotion-focused adapting techniques (Carver *et al*., 1989). Problem-focused adapting means to issue settle or to accomplish something to change the wellspring of the pressure. Emotion-focused adapting means to lessen or deal with the passionate trouble that is related with the upsetting occasion (Carver *et al*., 1989). Curiously, people encountering a similar fiasco over a broadened timeframe may shift in their vulnerability (Norris, 2002). It appears that adaptation strategies employed by smlaaholder farmers for drought differ area to area, and it has been covered that those strategies can either be reactive or proactive (Nebilwi *et al*., 2021). According to Nelson *et al*. (2007) adaptation is a procedure of think change fully expecting outside changes or stresses. Researchers agrees with the across the board comprehension of the part of adjustment as a procedure of consider change to manufacture flexibility and defeat the negative impacts of shocks and change (Stringer *et al*., 2009; O'Farrel *et al*., 2009; Burton *et al*., 2002).

The ability to stay away from, adapt, modify or adjust is a noteworthy factor in describing vulnerability and critical with regards to drought chance decrease. Adaptive at small scale level is comparative or firmly identified with other generally utilized ideas, for example, coping limit, administration limit, strength, vigor, adaptability, and flexibility (Smit & Wandel, 2006). IPCC (2001) portrays adaptive as the potential or capacity of a framework, district, or network to conform to the impacts or effects of environmental change. The ability to adjust is setting particular and changes from nation to nation, from network to network, among social gatherings and people, and after some time. McCarthy *et al*. (2001) think about adaptive as a component of riches, innovation, instruction, data, aptitudes, foundation, access to assets, and soundness and administration abilities. The adaptive of a framework or society mirrors its capacity to alter its attributes or conduct to adapt to existing or foreseen outer burdens and changes in outside conditions.

Connection between government, governance and adaptive policies at national level and the adaptive capacity of farmers at local level are of critical importance. Farm level adaptive capacity is probably not going to be adequate in poor regions and under-developed economies without sufficient markets and resources (Lotze-Campen & Schellnhuber, 2009). The study by Eakin & Lemos (2006), find that globalization; the removal of agricultural subsidies; and increased import competition diminish the adaptive capacity of farmers to climate shocks, especially in developing countries. In this manner there is a requirement for national and international strategies that consider and support adaptation in the agricultural sector at local level recommend the change of agricultural policies in developed countries to provide for better options for the smallholder farmer to increase their resilience to drought (Lotze-Campen & Schnellnhuber, 2009; Belliveau *et al*., 2006; Easterling *et al*., 2000). Lotze-Campen &

Schellnhuber (2009) include enhanced strategies that guide arrive utilize changes, regulation of migration patterns, and grants and material help for alternatives livelihood options to the set of policies that can increase resilience while Easterling *et al.* (2007) argue for the establishment of accessible markets and financial services as preconditions for adaptation under climatic shocks.

According to Zarafshani *et al*. (2016); Burton *et al*. (2002); Rosenzweig & Tubiello (2007) specify that adaptation in agriculture is the standard instead of the exemption, and those smallholder farmers in the past exhibited adequate adaptive ability to adapt to extraordinary climate occasions on short-, medium-and long haul time scales. Imperative, nonetheless, to note is that the adaptive of agriculturists are controlled by education or human capital; wealth; material resources; societal entitlements; information; technology; infrastructure; and resources (Ngcamu & Chari, 2020; Zarafshani *et al*., 2016)

For quite a long time drought became one of the principle challenges for livestock farmers in Africa. Livestock farmers reacted differently through time. With land available in abundance, farmers used avoidance strategies by adopting a nomadic system where they moved from drought-stricken areas to areas with good supply of feed and fodder. Increased pressure on land forced farmers to respond in different ways. Coping with drought is considered a short-term response to feed and fodder shortages (O'Farrel et *al.,* 2009). Eriksen *et al*. (2005) describe coping mechanisms as the actions and activities that take place within existing structures and systems; examples are when farmers introduce on-farm diversification such as diversification of feed and fodder sources or alternative livestock types.

O'Farrel *et al.* (2009) argue that how farmers respond to drought is a function of several variables related to the severity, frequency and duration of droughts. In addition, farming practices and the farming system determine the type of response mechanisms, for example nomadic and transhumant pastoralists can apply evading strategies while ranchers and crop farmers have to adopt an endurance strategy (O'Farrel *et al.,* 2009). Adjustment strategies vary from coping mechanisms in the sense that they are more permanent, and adjustments need to be initiated prior to droughts. In a sense, adjustment can be viewed also as adaptation but the literature proposes adaptation as a permanent and long-term strategy that affected livelihoods and lifestyles (O'Farrel *et al.,* 2009). Adjustment strategies include strategies such as:

- Change of livestock type
- Change in grazing strategies

- Farm level diversification
- Economic diversification
- Insurance
- Building of fodder banks
- Permanent reduction of grazing capacity
- Water reticulation
- Planting of drought resistant crops
- Budgeting and financial planning for droughts

There are several reasons to invest in rain fed agriculture as part of a drought coping strategy with varying opportunities per place. Suitable climate for rain fed agriculture present great potential to improve productivity where yields are still low in many regions of sub-Saharan Africa (CA, 2007). Good agricultural practices (through management of soil, water, fertility and pest control), upward (inputs, credit) and downward (markets) linkages combined with weather insurance schemes can go a long way in improving agricultural productivity with little impact on water resources (CA, 2007).

Water conservation is being used by smallholder farmers of which it has also become a priority. Farmers are trying by all means in ensuring that they save much water as little they have. This has called for the improvement in irrigation system, where about 83% smallholder farmers are preferring to use drip irrigation under minimal tillage, as it is water efficient. Several other studies have also recommended the zero-tillage approach, or mulching as means to help conserve soil moisture by reducing evaporative losses (Nebilwi *et al*., 2021).

2.8 Theoretical Framework

Agricultural systems comprise of a basic production unit, i.e. the farm, which has its own particular limitations, imperatives and countenance a heterogeneous decision-making environment (Pienaar & Traub, 2015). Given this t diversity inside agricultural frameworks, different arrangement plans have been developed and produced over a period of time (van der Ploeg *et al*., 2009). The basic steps in creating farm typologies are well documented in the literature and have tailed one or a mix of two primary methodologies: subjective frameworks and quantitative (Righia *et al*., 2011; Laoubi & Yamoa, 2009). Recently many studies have utilized the quantitative approach in order to create farm typologies (Gelasakis *et al*., 2012; Bidogeza *et al*., 2009; Laoubi & Yamoa, 2009; Emtage *et al*., 2005). The quantitative framework approach is utilized to build up the typology of farm households in this analysis due to its quality in recognizing groups without biasness in view of likelihood hypothesis (van Averbeke & Mohamed, 2006).

To develop the typology of farming households includes the choice of the theoretical framework on which the classification will be based on. As indicated by Emtage (2004), a wide range of theories have been utilized as a framework to create farm typologies which include farming styles (Vanclay *et al*., 2006; van der Ploeg, 1994), sustainable livelihoods (Righia *et al*., 2011; Tittonell *et al*., 2010; Babulo *et al*., 2008; Perret *et al*., 2005), farming context (Kaine & Lees, 1994) and market structure (Barr, 1996). The theoretical framework adopted here is the sustainable livelihoods framework, a multi-disciplinary approach which seeks to not only look at agriculture, but includes economic, social, environmental and political perspectives (Scoones, 2009). According to Ashley & Carney (1999), this approach is based on the ever-changing thinking about poverty reduction, the way poor people live their lives and the importance of structural and institutional issues.

The start of sustainable livelihoods is that the adequacy of advancement endeavours can be enhanced by efficient investigation on neediness and its causes; a superior educated comprehension of the open doors for improvement and its effect on livelihoods; and setting individuals and the needs they characterize as the focal piece of the examination (Ashley & Carney, 1999). This framework is picked because of its strong association with rustic progression research and its quality in delineating arranged assortment at a system level.

Furthermore, understanding diversification among farming, SL takes into consideration dynamic analysis of the distinctive systems farming households attempt to accomplish with higher expectation for everyday life. This is done looking at various attributes that would characterize particular farming systems and includes income and expenditure, household characteristics, production activities and socio-economic indicators. This framework recognizes a specific livelihood encompassing more than just income by also including social institutions, gender relations, property rights and a few others which would influence the strategies adopted by rural households (Ellis, 1998).

This methodology sees the noteworthiness of the household as the basic leadership unit which develop decisions on the families' accessible assets, targets, individual and financial perspectives and the standards and standards of establishments that regulate the usage of assets accessible to the family (Emtage, 2004). It has been used broadly in the progression of farm typologies (Perret *et al*., 2005; Dorward, 2002) previously and the aftereffect of the sustainable work approach is proposed to improve the occupations of poor family units upgrading their levels of thriving, food security, income and biophysical condition (Emtage, 2004).

The sustainable livelihoods framework (Figure 2.2) is a push to conceptualize livelihoods comprehensively, catching the numerous complexities of livelihoods, and the imperatives and openings that they are subjected to. These requirements and openings are formed by various components, extending from worldwide or national level patterns and structures over which people have no control, and may not know about, to more nearby standards and establishments and, at long last, the resources for which the family units or individual has coordinate access. Until further notice, we will utilize the household as a unit of investigation. It is vital to perceive that not all people inside a household unit have level with basic leadership power, or advantage similarly from household unit resources or salary.

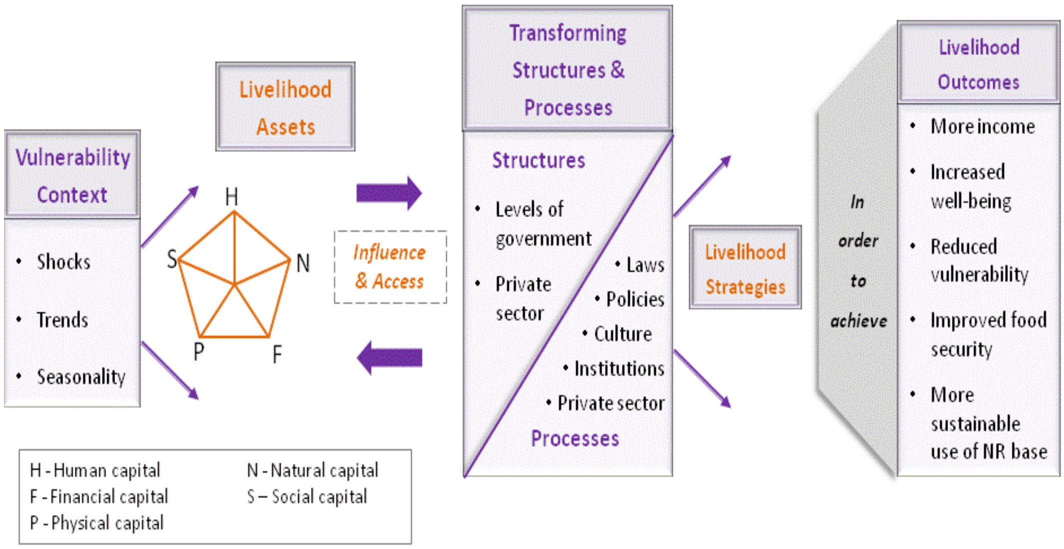


Figure 2.2: Sustainable Livelihood Theoretical Framework

(Adapted from DFID, 1999)

The vulnerability context in the above figure refers to the external environment in which people live, that also comprise of trends, shocks, and seasonality. The vulnerability context's three factors have a direct impact on the possibilities to earn a living now and in the future among poor people. Wider economic conditions, seasonal shifts in prices, production and employment opportunities can create more or fewer opportunities and are regarded as the most enduring sources of hardships for poor people all over the world; an illness in the family can deprive a family of an important source of income and can force them to sell important assets that they have built up.

The transforming structures and processes' box alludes to the organizations and approaches that influence poor people groups' lives, from open and private elements to national strategies and local culture. These can change both the vulnerability setting and the advantages for which destitute individuals approach. The possibility of benefits is fundamental to the sustainable livelihoods approach. As opposed to understanding neediness as just an absence of wage, the sustainable livelihoods approach considers the benefits that needy individuals require with a specific end goal to manage a sufficient pay to live.

In view of those benefits moulded by the vulnerability context and the transforming structures and procedures, needy individuals can attempt a scope of livelihood strategies - exercises and decisions - that at last decide their work results. Needy individuals are typically obliged to consolidate a scope of techniques all together essentially to survive; people may take part in various exercises, and the distinctive individuals from a household may live and work in better places. The results that they may accomplish, all being admirably, could incorporate more wage, expanded prosperity, decreased vulnerability and more prominent sustenance security. Now and then one result can contrarily influence another; for instance, when destitute individuals take part in less hazardous and thus bring down pay exercises, with a specific end goal to be less helpless against stuns. Five sorts of advantages, or capital as they are depicted in the writing, have been distinguished that we as whole, not simply needy individuals require with a specific end goal to bring home the bacon. These are the human, social, normal, physical, and money related capitals.

The more resources any household approaches, the less helpless they will be to negative impacts of the patterns and shocks as depicted above, or to seasonality, and in this way the more secure their livelihood are. Commonly expanding one style of capital can cause an ascent in various measures of capital, for example, as people become educated (increment in human capital) they will land a more strong position that gains additional cash (increment in financial capital) that progressively infers that they are prepared to redesign their home and offices (increment in physical capital). In some cases, be that as it may, one assortment of capital reductions as various will increment. This may be valid, for example, wherever somebody or household pitches their property to move to a town.

Lately the significance of the five capitals has been condemned by advancement professionals for concentrating an extreme measure of on the micro-level and dismissing the 'higher' levels of administration, the strategy condition, national and worldwide economic process so on. This has driven, for example, to a confined comprehension of how showcases function; how forms a long way from the lives of needy individuals in any case enormously affect the probabilities that exist for them to acquire a safe monetary profit. These issues are in actuality caught inside the more extensive sustainable livelihoods framework, inside the changing structures and forms and the 'vulnerability setting' in any case, by and by, many have utilized the possibility of the five capitals more than they have the linkages among those and consequently the more extensive surroundings inside which individuals live. It is vital to remember that the more extensive surroundings influences not exclusively the advantages for which people approach, anyway additionally what might be accomplished with those benefits.

The sustainable livelihoods framework has likewise been condemned for neglecting to take control elements into thought, since it identifies with sexual orientation, for example. Once more, though such elements square measure encased inside the framework, in tail, they require been ignored. Particularly, social capital has regularly been viewed as just 'a shrewd thing' though, actually, interpersonal organizations might be every thorough and selective, with ordinarily the weakest and most powerless rejected. The majority of the reactions and constraints of the Sustainable Livelihoods approach are certainly legitimate. In any case, it stays exceptionally accommodating for this study, each to consider the simple farm level subtle elements of poor smallholder farmer's livelihoods and for considering the more extensive setting inside which those livelihoods work. The conceptual framework for the study is attached in the next page (Figure 2.3).

2.8 Conceptual framework

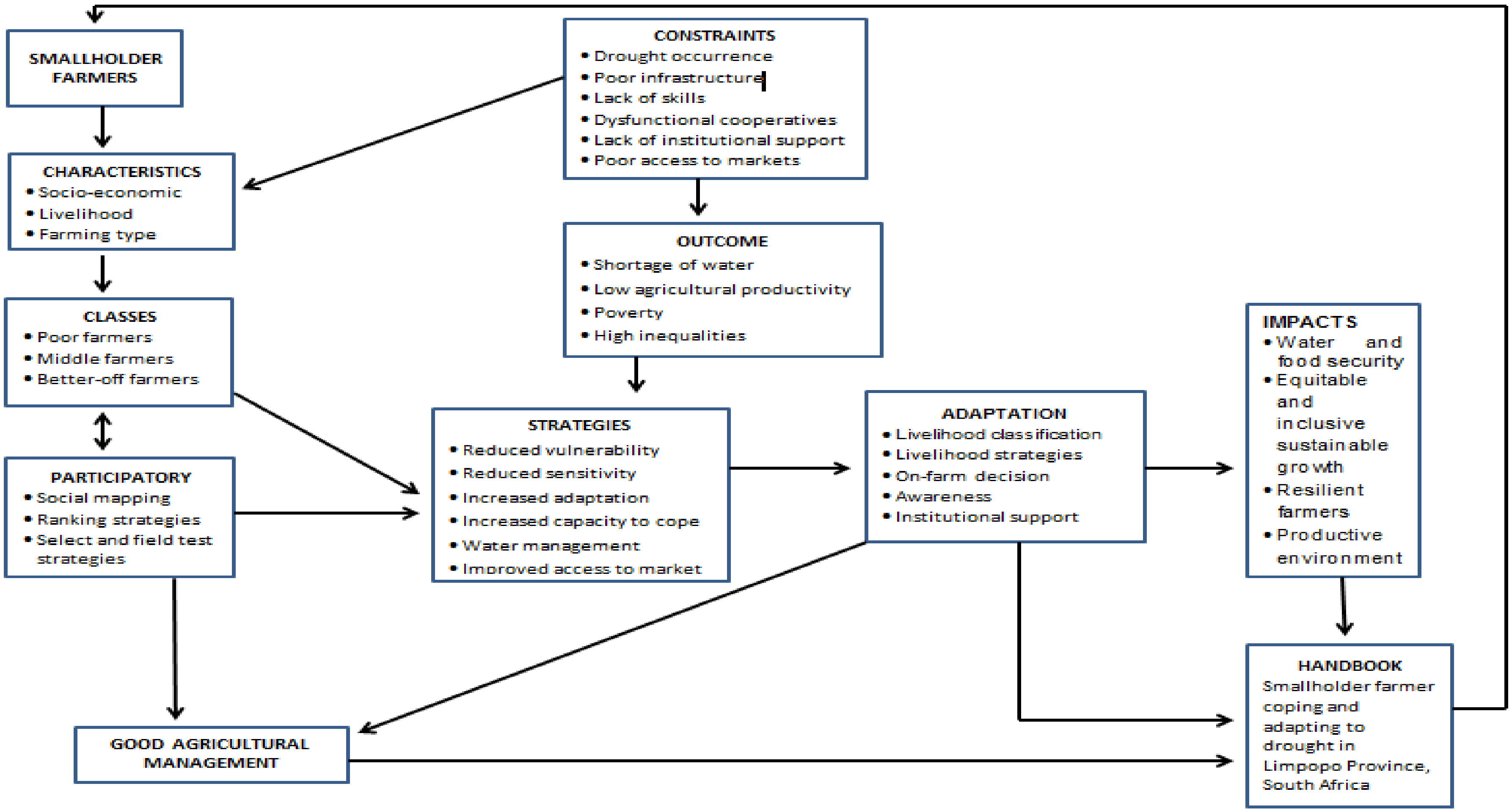


Figure 2.3: Conceptual framework

2.9 Conclusion

Agriculture is the backbone and fundamental source of livelihood in Limpopo province. However, it is the most sensitive and affected sector by climate change, threatening the livelihoods of the rural poor and making them exposed to food insecurity. Climate change and variability have an impact on agricultural performance and production through droughts, floods, pests, and diseases that affect crops and cattle. Most smallholder farmers in rural regions are severely affected by these effects. They are the most susceptible category due to their reliance on climatically sensitive, rain-fed resources. Some farmers are adapting by adjusting planting dates, intercropping, and diversifying, while some smallholder farmers are slower to react due to a general lack of information, competence, and data on climate change problems. Any push to expand the commitment of smallholder farming to poverty reduction needs to value that smallholder farmers are not a homogeneous group. A viable smallholder agricultural development strategy must perceive that there are diverse classifications of smallholder ranchers requiring distinctive help and methodologies. Mechanical and institutional bundles ought to be custom fitted for every class of agriculturists. This can only be done if the characteristics and livelihoods of the farmers are understood, and the strategies are developed according to the livelihoods and resource endowment.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines methods applied to answer the research questions as well as achieving the aims and objectives of this research. The research dealt with a systematic approach to drought adaptation strategies of smallholder in the Limpopo Province. The study followed a field and experimental research design approach and incorporated the preliminary scoping visits; identification of the study sites; comprehensive literature review and data collection; household survey; transect walk; focus group discussions; key informant interviews; data analysis; and statistical tests.

3.2 Sampling

3.2.1 Identification of the study sites

Literature and papers on the Limpopo Province were reviewed before the research began. The review found that Mopani and Vhembe districts are more vulnerable to the impacts of climate change such as droughts and identified as a suitable area for this study. In a thorough analysis of the agricultural climate in the province, the LDARD found that severe drought conditions are present in the majority of the province (LDA, 2016). The whole Mopani district, the municipalities of Musina, Thulamela, and Mutale in Vhembe, Greater Letaba, Greater Giyani, and Ba-Phalaborwa in Mopani, and the municipalities of Fetsakgomo and Makhuduthamaga in Sekhukhune are among the worst-affected areas (Mpandeli *et al*., 2019; BFAP, 2016). LDA, 2016).

Smallholder farmers were particularly hard hit by the present drought in the regions of Mopani, Vhembe, and Sekhukhune (LDA, 2016). Sekhukhune was left out of this study since a study on coping with climate variability in the Limpopo Province had already been done in that district. The Mopani and Vhembe districts were chosen as past research indicates that they are climate hotspots (Petrie *et al*., 2015). In Mopani, the Greater Tzaneen and Greater Giyani local municipalities were chosen, while the Thulamela Municipality was chosen for the study in Vhembe. Due to the large number of smallholder farmers who depend on agriculture for a living and the significant temperature fluctuations between the regions, the three municipalities were chosen. The key criterion for selecting the places was the incidence of drought. Drought is a common occurrence in the Limpopo Basin. A drought in the area is reported to occur approximately once every 10-20 years, but its frequency is not always predictable (FAO, 2004).

Drought is difficult to define and monitor because to its broad geographical and temporal distribution. Drought is commonly studied based on rainfall occurrences using Standardized Precipitation Index (SPI). The SPI calculates the deviation of rainfall events from the long-term mean over a certain time frame. The South African Standardized Precipitation Index for the month of December 2016 is shown in Figure 3.1. Drought conditions ranged from severe to acute in several areas of the Mopani and Vhembe districts. The size of the farms, their ability to be rainfed, and the agro-ecological zone of the region were all taken into consideration while deciding on the placements.

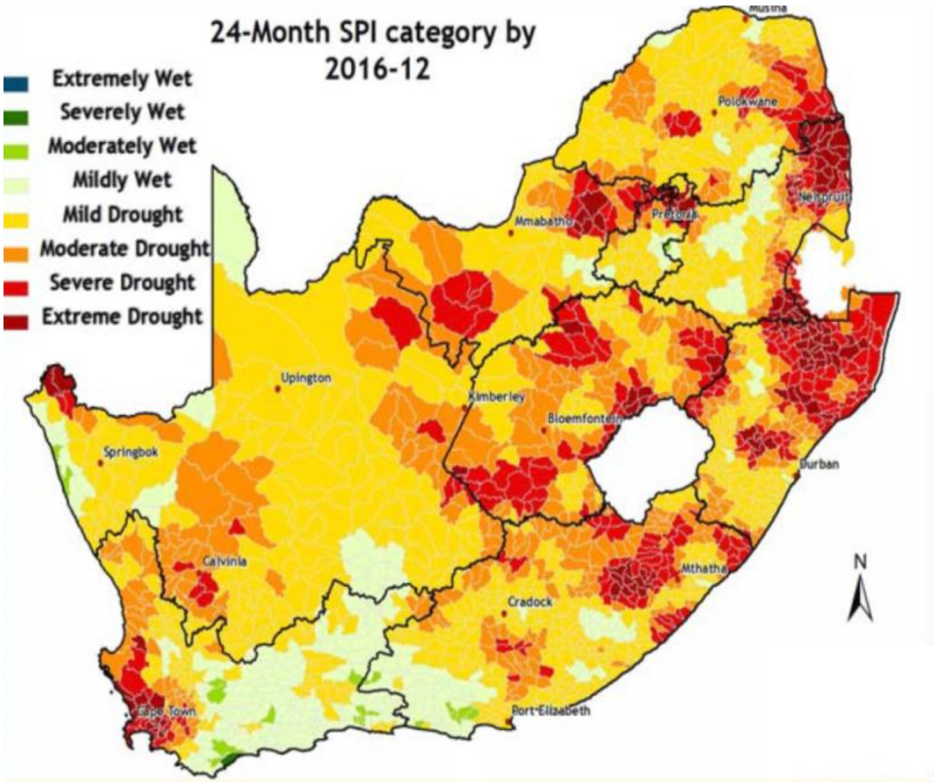


Figure 3.1: Standardised Precipitation Index for December 2016

(Adapted from SAWS, 2017)

3.2.2 Sample selection

In this research, the unit of enumeration was the home. Households are composed of individuals living on a homestead, spending most of their time with each other, and eating from the same pot. This excludes domestic employees and family members who live far from the farmhouse. A random stratified sample of homes was used to create a representative household survey sample. Stratified sampling makes ensuring that the sample accurately represents the relevant strata of the population (Durrheim & Painter, 2006). The sample was constructed in such a manner that it represented the complete population from which it was obtained (Jennings, 2001).

To agree on the sample units, a meeting was scheduled with each municipality's Agricultural office. Municipal agricultural services are organized into sections called centers, which are separated geographically. It was thus critical to interview farmers from all strata, since there were likely to be differences in access to water resources, markets, and extension services. A total of 200 rural families were recruited from 8 different centers (Berlyn, Naphuno, Mamitwa and Tzaneen service centres in the Greater Tzaneen Municipality; Guwela, Mhlava Welemu and Hlaneki service centres in the Greater Giyani Municipalityand Lambani and Khalavha service centres in Thulamela Municipality). The research only included smallholder farmers who farm under dryland and mixed farming systems.

The sample was stratified across the three municipalities. Stratified sampling may be done in two ways: proportional or disproportionate stratified sample (Durrheim & Painter, 2006). While the latter oversamples some strata relative to others, the former chooses the same percentage from each stratum as occurs in the population. Because it was unclear how many farmers were working in the three towns, disproportionate stratified sampling was employed in this research.

3.3 Comprehensive literature review and data collection

The study began by conducting a detailed literature review of various studies on smallholder farming at global, regional, national, provincial and municipality's level. The relevant literature included studies and reviews of the history of land reform, livelihoods in rural South Africa, and opportunities and constraints that smallholder farmers have faced to cope with drought. The focus of the literature review was on land tenure arrangements, the impact of social grants and other off-farm livelihoods on smallholder farming, strategies to cope with drought, and the current support systems that are provided to smallholder farmers such as extension, training, and financial resource support. Theories related to smallholder farmers were also reviewed to understand the underlying causes of the behaviour of smallholder farmers in pursuing their livelihoods in Limpopo Province. These include debates on smallholder versus commercial farming, farming type, capital accumulation, and typologies of differentiating smallholder farmers.

Primary data were collected over a month with the aid of a local translator, during the month of December 2017 and January 2018. This process utilized a combination of extensive and intensive research approaches. Swanborn (2010) defines an extensive research approach as the collection of information about the relevant properties of many instances of a phenomenon. Each survey respondent provides information based on a standardized set of questions that are aggregated over all the respondents to create information about relationships between the variables under study, to enable understanding and explanation of the phenomenon. Putting all this information together, and calculating and interpreting correlations between properties of these examples, enables one to draw conclusions (Swanborn, 2010).

An intensive research approach, on the other hand, focuses on a specific instance of the phenomena to be studied, or a handful of instances, to study the phenomena in great depth (Swanborn, 2010). Each instance is studied in detail in its own specific context. Data using this approach are collected using a variety of methods such as in-depth interviews, focus group discussions and observations. The different types of interviews conducted during the study included a household survey, interviews with extension staff, and interviews with the institutional representatives. This provided a wide range of information that could be triangulated across the different methods.

3.3.1 Sustainable Livelihoods Framework

Components of the Sustainable Livelihoods Framework (DFID, 1999) were used to collect farmer characteristics and livelihoods data. Livelihood refers to how people make a living, comprising of the capabilities, assets and activities required to live (Dorward *et al*., 2009). Peoples' livelihoods also depend on the social relations they draw on, to combine; transform; and expand their assets and on the how they deploy and enhance their capabilities to act and make their lives meaningful. The notion of livelihood rarely refers to a single activity but includes complex, contextual, diverse, and dynamic strategies developed by households to meet their needs. Livelihood's research focuses on the actualities of the lives of members of poor and vulnerable groups to determine how these groups make their living in the context of risk and stress (Dorward *et al*., 2009). The five main assets of the Sustainable Livelihoods Framework were used for data collection; human, physical, natural, financial, and social assets that make the livelihoods of people; in this case the smallholder farmer livelihoods.

3.3.2 Household survey

A household survey involves interviewing people using a list of pre-determined questions on a selected topic using a questionnaire. The aim of the interview is to ensure that the same questions are asked in the same order across a sample of people representative of a population. This has the advantage of making the cases comparable. Household surveys are useful for descriptive, explanatory, and exploratory purposes (Babbie & Mouton, 2011). The intention is to explore, describe and explain the characteristics of the smallholder farmers based on livelihood variables. Surveys have the advantage of enabling researchers to be able to collect original data for describing a population too large to observe directly through probability sampling. Surveys are thus generalizable to the population from which the sample has been drawn, provided probability sampling is used. The disadvantages of household surveys are that non-response can be prevalent, it is difficult to collect and probe sensitive information using a questionnaire, and it is sometimes difficult to verify the accuracy of the information collected before the analysis stage, by which time it is too late to repeat fieldwork. The information captured through the household questionnaire appeared to be reasonably reliable. The interviewees freely responded to the questions asked, even though some of the information provided was based on recall rather than records.

3.3.3 Questionnaire design and data collection

The questionnaire was designed around the assets of the Sustainable Livelihoods Framework (DFID, 1999) as a means of exploring participants' livelihood strategies. The study gathered both primary and secondary data to accomplish the research objectives and to answer the research questions. Secondary data was gained through wellsprings of confirmation including records, authentic materials, published and unpublished articles, web sources and books, while primary data were gathered through organized questionnaires. Open-ended questions enabled the members to give point by point data on the encounters, feelings, convictions, certainties, and states of mind about how smallholder farming contributed to giving food security to their households. Closed-ended questions, then again, enabled the participants to pick the appropriate responses from the choices gave to the questions, including the sorts of advantages they had. The questionnaires were disseminated to all sampled households in the study area, and participants were helped to complete the questionnaires were vital. The authorities from LDARD conveyed their Extension Officers to aid both moving toward the participants to evoke their interest and administration of the questionnaires.

3.3.4 Transect walk

A transect walk is a method for outlining the location and distribution of resources, features, topography, and mainland uses along a particular transect (Fauna & Flora, 2013). Before conducting the actual interviews, a transect walk is frequently helpful for understanding the context and seeing the "whole picture." It is useful for identifying and characterizing the cause-and-effect relationship between terrain, vegetation, farming, and other production activities, according to Fauna & Flora (2013). A quick transect walk around the municipality's agricultural regions will be done to capture numerous physical and socioeconomic variables that affect farmer livelihood. This was accomplished with the aid of a key source in the area. Through observation of both active and vacant plots, the transect walk will give a general indication of the degree of farming activity at the communities.

3.3.5 Key informant interviews

Interviews with key informants include interviewing a small group of people who are experts in the topic under inquiry (USAID, 1996). The essential aspects stressed in this definition are that these interviews are mostly qualitative and informally structured, relying on a list of topics in the key informant guide, and that the person being questioned should have first-hand knowledge of the issues being addressed (Ncube, 2017). When there is a need to understand the motivation, behavior, and viewpoints of the respondents, and when the primary goal is to provide suggestions, key informant interviews are useful to help interpret data acquired via other approaches (USAID, 1996; Kumar, 1989). All of these characteristics will be significant in this study since the researcher needs context to evaluate the home data survey of farmers and comprehend the opinions of other role players. The study's overarching goal is to produce specific suggestions on how smallholder farmers in rural Limpopo Province can cope with and adapt to drought.

Having in-depth knowledge of their domains, informants offer data and insight and can also provide information about local phenomena that explain why things happen (Kumar, 1989). The drawbacks of key informants include the possibility of bias if informants are not properly recruited, as well as vulnerability to interviewer (USAID, 1996; Kumar, 1989). According to Patton (2002), the risk of relying too much on key informants is that it causes one to lose sight of the reality that their viewpoints are unavoidably restricted, selective, and prejudiced. Thus, triangulation of information from important sources is critical. Choosing the right key informants is an important first step in eliminating some of these inherent biases. Key informants chosen had deep knowledge of the issue, and persons should also grasp the demographic characteristics of the group to be questioned. It is first necessary to identify the relevant groups from which key informants can be drawn, then select a few informants from each group, according to Kumar (1989).

Key informants in the research study included district managers, service center managers, and extension officers from the LDARD. Most of the irrigation farmers received information about additional help services from them. Researchers would therefore conduct separate semi-structured interviews with them to better understand their roles, the challenges they face, how long they have worked at the rain fed, how they have assisted the farmers, and what solutions are required in their opinion to help smallholder farmers cope and adapt to drought. The officials from program support office in the DAFF also serves as a key informant for institutional support. These informants provided useful information concerning the funding model, farmers support, and their affiliation with the government.

3.3.6 Focus group discussions

A focus group discussion is a type of group interviewing that brings together people facing similar problems for an interview with a researcher. Group interviews and focus groups talks are distinguished by (Gibbs, 1997; Kumar, 1987) by highlighting that in the former, the participants reply to the interviewer's questions, but in the latter, the emphasis is on group interaction while the interviewer plays a moderating role. The farmers committee will participate in a focus group discussion to better understand the structure and operation of the organization. The focus group method was used to conduct interviews with the farmers committee since they are a cohesive group that manages farmer issues most of the time (Ncube, 2014).

Focus group discussions are used to quickly create a huge number of ideas, thoughts, feelings, and views from many people on the same subject (Elliot & Associates, 2005; Gibbs, 1997). This is perfect for when you interview smallholder farmers to acquire a more comprehensive understanding of how they deal with drought and what measures they should use. According to Kumar (1987), effective focus groups should ask open-ended questions that begin with the words "what," "why," "how," "when," and "which." This makes it possible to have a conversation instead of giving simple yes-or-no answers. A focus group discussion guide was created for this study. The categories of the discussion subjects that was covered included the development of the committee, problems, achievements, and drought management plans.

Focus group talks have the advantages of allowing participants to express themselves more freely in a group setting, allowing participants to ask questions that the researchers may not have thought to ask, and revealing a wide range of viewpoints on a subject (Kumar, 1987). Focus groups have a number of drawbacks, including the difficulty in organizing them, the difficulty in obtaining sensitive information through groups, and the possibility that groups won't be completely confidential or anonymous because concerns will be discussed in a group (Gibbs, 1997). The logistics, the appropriate questions to pose to farmer groups, which groups should be interviewed, and how many individuals should be interviewed are all practical considerations while holding a focus group discussion (Ncube, 2014).

3.4 Data analysis

The process of reorganizing data into digestible themes, patterns, trends, and correlations is known as data analysis (Mouton, 2001). According to Mouton, the goal of data analysis is to comprehend the many constituent aspects of one's data by inspecting the connections between ideas, constructions, or variables. Data interpretation follows data analysis and seeks to relate and evaluate one's data and findings to more general theoretical frameworks and paradigms. In order to evaluate crop profitability and productivity, gross margin analysis was performed. The results were compared to data from the DALRRD computerized enterprise budget, provincial statistics for Limpopo, national statistics, and data on agricultural planting rates, production costs, and gross margins.

By creating topic tree diagrams and comparing themes, qualitative data from interview transcripts and voice recorders was analyzed (Elliot & Associates, 2005). The information was examined for recurring themes, patterns, and strongly held beliefs. The diversity and complexity of participant experiences, perceptions, and expressions were also taken into account in research analysis, as suggested by I-Tech (2008). In life history analysis, the themes and problems that surface from the data are organized into a framework that shows the connection between the various factors and the participants' perceptions of their past, present, and future (Francis & Le Roux, 2012).

3.5 Statistical tests

A statistical package for social sciences (SPSS) software program was used to enter, code, and analyse the information from the questionnaires. There were several analyses conducted, including the generation of descriptive statistics and forms of statistical analysis, such as comparison of mean and proportion. Through conducting thematic tree diagrams and engaging in a comparison of the themes found in interview transcripts and voice recorders, qualitative data were analysed. A theme, a trend, and opinions that emerged frequently were analysed. Participants' experiences, perceptions, and expressions were also considered in the analysis. Multiple data sources were used to collect information about drought conditions, impacts, events, drought adaptations, and coping strategies, including socio-economic interviews, focus group discussions, observation, and informal interviews with smallholders.

For the statistical data analysis, the 2021 TIBCO STATISTICA Version 14.0.0.15 TIBCO Software (data analysis software system) was utilized. A repeated measures Analysis of Variance (ANOVA) for rainfall, minimum and maximum temperatures as well as CMI were assess for the statistical significance. Statistical regression analysis (ordinary regression) over time was done to determine if there was a long-term trend in the average rainfall, minimum and maximum temperatures as well as CMI rainfall over the interval of 1960 to 2018.

The statistical data analysis, the StataCorp. 2021. Stata Statistical Software: Release 17. StataCorp LLC: College Station, TX, USA [12], was utilized to assess how smallholder farmers adapt to drought and factors that influence implementation strategies. To understand the factors that determine the capacity building of smallholder farmers, the study employed a binary probit model. The probit model is a statistical probability model with two categories in the dependent variable (one and zero). Probit analysis is based on the cumulative normal probability distribution.

CHAPTER FOUR

IMPACTS OF RAINFALL AND TEMPERATURE CHANGES ON SMALLHOLDER AGRICULTURE IN THE LIMPOPO PROVINCE, SOUTH AFRICA

The following paper has been published as part of this chapter:

Shikwambana, S.; Malaza, N.; Shale, K. Impacts of Rainfall and Temperature Changes on Smallholder Agriculture in the Limpopo Province, South Africa. *Water* 2021, *13*, 2872. https://doi.org/10.3390/w13202872.

Abstract

The intensity and frequency in the recurrence of extreme climate events are compounding the vulnerability of smallholder farmers, who have always lacked the resources to adapt. The increasing temperatures and decreasing rainfall are exacerbating water scarcity challenges through drought recurrence. There is an urgent need for pathways that lead towards Sustainable Development Goals, mainly Goals 1 (no poverty) and 2 (zero hunger) in poor rural communities. This study assessed rainfall and temperature trends from 1960 to 2018 and their impacts on crop production in the Mopani and Vhembe Districts of Limpopo Province, South Africa. Trend analysis was used to analyze rainfall patterns, as well as the trends in temperature recorded for the past 58 years. The climate moisture index (CMI) and runoff estimates were used to assess the degree of aridity and water availability, respectively. Geographic Information Systems (GIS) and remotely sensed data were used to assess the changes over time. The total annual rainfall has declined significantly while annual minimum and maximum temperatures have increased significantly during the period under observation. An aridity index of −0.70 calculated for the study areas classifies the districts as dry and water scarce. The results of the analysis also indicate that the districts are climate change hot spots and are highly vulnerable to the impacts of climate change. The changes are compounding water and food insecurity. Policy and decision-makers should focus on enhancing adaptation and resilience initiatives in the study areas through systematic, transformative, and integrated approaches, such as scenario planning, circular economy, and nexus planning.

Keywords: climate change; resilience; adaptation; climatic moisture index; sustainability.

4.1 Introduction

Climate change and variability are some of the greatest challenges facing humankind and have dominated the agendas of major world conferences (IPCC, 2007). Sub-Saharan Africa (SSA) is identified as one of the climate change hotspots, as the impacts of cli-mate variability and change are adversely affecting livelihoods and threatening to de-rail the economic gains in the past (IPCC, 2007; Nhamo *et al*., 2019). As part of SSA, South Africa has also been affected by extreme weather events that are affecting crop production, threatening national food security (IPCC, 2007; Nhamo *et al*., 2019). South Africa has already experienced shifts in the crop growing seasons and has been subjected to severe droughts, for example, those recorded during 1982/83, 1987/88, 1991/92, 1994/95, 2002/03, 2008/09, and 2015/16 (Nhamo *et al*., 2019; BFAP, 2016). The worst droughts were experienced during 1982/83, 1991/92, and 2015/16 seasons, when compared with other droughts periods or seasons (BFAP, 2016; Cogato *et al*., 2019). The 2015/16 El Niño Southern Oscillation (ENSO) induced drought was the worst since the beginning of recording weather information, as the whole country became water, energy, and food-insecure (BFAP, 2016).

In the Limpopo Province of South Africa, smallholder agriculture is intensely reliant on rainfall (van Koppen *et al*., 2017), making it highly vulnerable to the impacts of climate change. Rural communities continue relying on climate-sensitive sectors of agriculture, forestry, and fisheries, exacerbating their vulnerabilities (BFAP, 2016). Particularly, the smallholder agriculture sub-sector needs to be adapted to the current changes, as it plays an important role in food security (BFAP, 2016). Thus, adapting and improving smallholder agriculture is a climate change adaptation strategy, providing pathways towards Sustainable Development Goals (SDGs) and national goals enshrined in the National Development Plan (NDP). Although the NDP intends to increase the irrigated area by 49,000 ha by 2030, the main challenge has been that almost all the available freshwater resources are allocated, and agriculture already uses over 60% of the available water resources (Cogato *et al*., 2019). The challenge is compounded by the decreasing rainfall, which has seen decreases in crop productivity in the smallholder sector, compromising food security (BFAP, 2016). Thus, rainfall is critical in determining agricultural yields where irrigation is not very advanced.

Understanding rainfall trends is critical in projecting future crop productivity under climate change and variability (van Koppen *et al*., 2017). Past studies have demonstrated that the changing climate has already impacted farming and food systems, as evidenced by shifts in the rainy season and modifications in the environment (Clements *et al*., 2011; Godfray *et al*., 2010; Hanjra *et al*., 2010; Brounn

& Funk, 2008; FAO, 2003). Climate change is causing agriculture to struggle to meet the growing food demands of an increasing population as the world is faced with water deficits and consequently low crop production (UNECA, 2002; Schilling & Hertig, 2002). The coping strategies being undertaken to reduce risks and vulnerabilities from the growing food and water demand are being hampered by a range of stresses that include higher temperatures, the emergence of novel infectious diseases, changing rainfall patterns, and shifts in the crop growing season (Camill, 2010). These current challenges require strategies that enhance the adaptation and resilience of particularly rural people, promote sustainable food systems, and build food systems that are more resilient to current harsh climatic conditions (Clements *et al*., 2011; Camill, 2010). Such initiatives are advance by promoting modern technologies that enhance and improve crop water productivity (Clements *et al*., 2011). An understanding of the various available adaptation options and the associated benefits are closely linked to the knowledge of how temperature and rainfall are to vary over time (Camill, 2010).

Rainfall variability and increasing temperature are already resulting in shifts in areas that are suitable for the growth of many crops (Davis & Vincent, 2017; Turral *et at*., 2011; Davis *et al*., 2010; IPCC, 2001), a situation requiring immediate adaptation strategies. This has seen the promotion of indigenous under-utilized crops that are generally adaptable to harsh conditions (Davis *et al*., 2010). Water demand has tripled since the 1950s, but the availability of freshwater has been declining (Gleick, 2003). According to Parry *et at*. (2001), the impacts of climate change on global food production may look small, but they are unevenly distributed in space and time (Parry *et al*., 2001). The challenge is more pronounced in arid and sub-humid tropics, particularly in poor regions where adaptation capacity is generally low (Parry *et al*., 2001).

This study assesses the trends in the monthly, seasonal, and annual rainfall, maximum and minimum temperatures, as well as the Climatic Moisture Index (CMI) in the Mopani and Vhembe districts of the Limpopo Province over a period of five decades. The two districts were chosen as past research indicates that they are climate hotspots (Petrie *et al*., 2015). We, therefore, highlighted climate change impacts in these districts at the local level to further recommend informed adaptation strategies. The premise was to guide policy and support decision-making to formulate coherent strategic interventions that lead to Sustainable Development Goals (SDGs) and the resilience of rural livelihood. The results add to the knowledge of past climatic variability and provide a platform to understand the future impact and can be used as an early warning tool. The methods can be used in other areas as climate change impacts and adaptation strategies are more effective at the local level.

4.2 Material and methods

4.2.1 Study Areas

The study focused on the Mopani and Vhembe districts in the Limpopo Province, South Africa (Figure 4.1). The two districts are identified as climate change hotspots in Limpopo Province (LDA, 2005). The Mopani district municipality is comprised of five local municipalities, namely, Greater Tzaneen, Greater Giyani, Letaba, Maruleng, and Ba-Phalaborwa. The district covers a total land area of approximately 1.4 million hectares, with a total population of 1.2 million people (IDP, 2012). The district is characterised by low rainfall especially in the lower areas of Giyani and Ba-Phalaborwa municipalities. The Mopani district experiences average maximum temperatures of 21 °C to 37 °C in January, average minimum temperatures of 5 °C to 12 °C in July and has annual average temperatures of between 13 °C to 27 °C (LDA, 2005). A large portion of the district, the eastward side of the Drakensberg escarpment, receives an annual average rainfall of about 400–500 mm, while the area at the foot and on the escarpment receives 600–800 mm and 800–1000 mm, respectively (LDA, 2005). Agriculture is one of the key economic sectors, which are predominant in the Tzaneen, Letaba, and Maruleng.

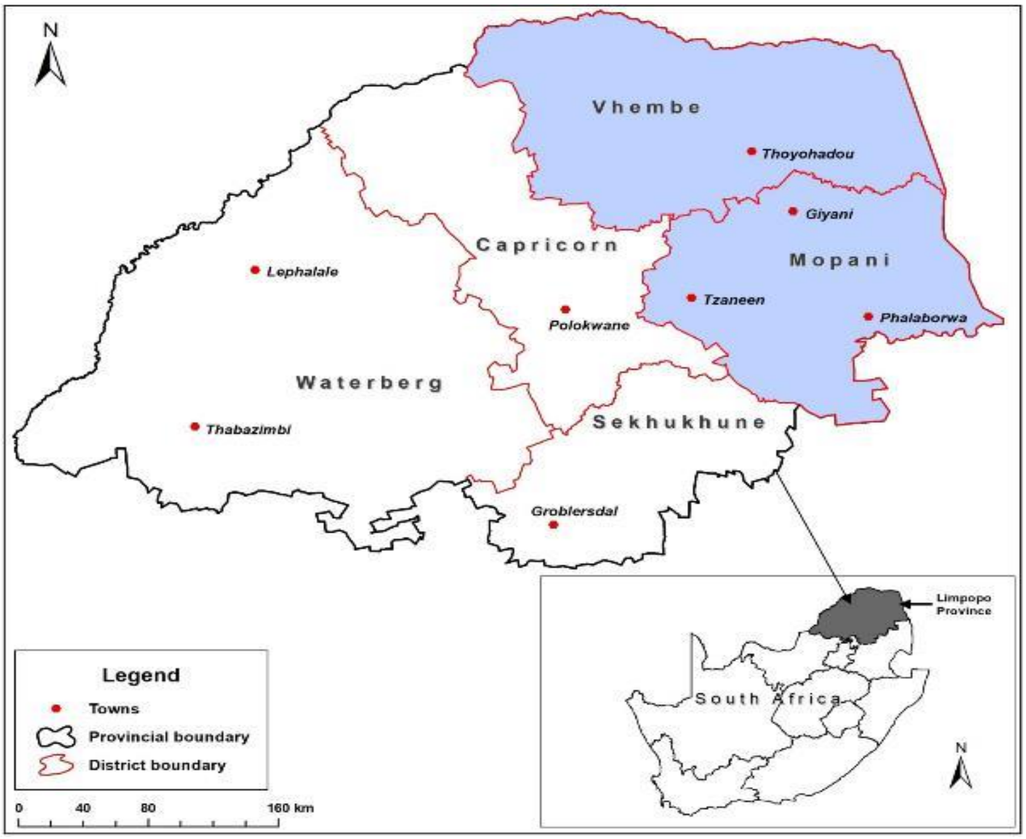


Figure 4.1: The Mopani and Vhembe districts in the Limpopo Province

The Vhembe district municipality is comprised of four local municipalities, Musina, Collins Chabane, Thulamela, and Makhado. It covers a total land area of about 2.6

million hectares with a total population of 1.3 million people (IDP, 2012). Average annual temperatures range between 14 °C and 29 °C (IDP, 2012). The district receives its rainfall in summer averaging between 300 mm and 400 mm per annum (DFED, 2004). The areas suitable for tropical and subtropical fruits are mostly in the Levubu Valley. Vegetables are produced in irrigation schemes that are spread along river valleys with the Nwanedi Valley, which is well known for tomato production (LDA, 2005).

The target group for this study are smallholder farmers who are a generally the most vulnerable group to climate change impact, as they do not have resources to adapt like their commercial counterparts do. Smallholders, who form the majority of rural people, have small land tenure of about 2 ha (Supplementary 1) and grow crops on a subsistence basis; however, they play an important role in household food security. The inability of smallholder farmers to adapt and be resilient to climate change is compounded by historical displacement that placed local indigenous people into Bantustans or former homelands, which are limited in resources. Agriculture in these former homelands is generally rainfed, an agricultural system which is highly vulnerable to climate change. This study, therefore, intends to inform policy and decision-makers on informed strategies that enhance the resilience of rural livelihoods.

4.2.2 Data sources

The geographical distribution description of the weather stations in the Mopani and Vhembe Districts, Limpopo Province comprising datasets of ≥50 years is given in Table 4.1. The dataset (daily rainfall, minimum, and maximum temperature) was obtained from the Agricultural Research Council (ARC) and the South African Weather Service (SAWS). For data quality, the climate data were inspected, and the missing values filled using the ARC stand-alone patching tool, which uses the Inverse Distance Weighting and the Multiple Linear Regression methods.

Table 4.1: The average annual rainfall in the Mopani and Vhembe districts

Station	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2018
Grenshoek (Sape)	1294.0	1313.3	831.8	1479.5	1659.1	1339.6	989.7	1413.6	2420.0	722.3	769.4	489.5	545.0
Phalaborwa-AER	663.9	323.3	303.1	836.6	847.9	765.3	550.4	641.5	845.0	386.1	744.1	279.7	280.6
Giyani-Amfarm	645.3	453.0	305.3	724.3	981.6	767.4	488.0	423.3	1156.0	614.8	563.4	272.3	393.4
Letaba	704.8	242.9	179.3	429.6	683.6	426.1	581.3	354.1	901.4	364.5	585.1	293.1	459.7
Mopani	763.7	353.8	264.4	813.4	796.6	950.8	442.8	491.5	1504.8	555.5	801.1	386.7	350.5
Bavaria Fruit Estates	1173.3	749.7	491.2	873.3	833.4	1339.6	702.4	616.9	1007.0	337.9	635.6	755.4	868.2

Mopani: Sekgosese	688.2	375.2	430.6	724.5	961.2	752.8	600.7	629.7	2044.9	641.9	781.6	407.7	588.8
Thohoyandou	1198.2	812.8	635.2	939.4	921.0	975.8	902.4	1191.3	170.3	802.5	1327.0	715.6	1026.0
Messina Proefplaas	302.4	204.6	352.5	538.3	473.1	499.4	353.8	248.5	1010.6	361.5	669.2	322.0	386.6
Levubu (S)	1233.3	728.5	547.7	1436.9	1327.9	1181.3	790.8	1100.4	2381.2	843.6	1331.2	670.4	934.6
Venda: Tshiombo	858.2	552.3	524.4	1208.2	1014.0	1183.6	760.9	1135.0	2996.8	845.1	1501.0	578.8	517.1
Venda: Lwamondo	1160.7	847.4	488.3	1408.1	1132.7	1258.3	874.6	1129.1	2607.1	704.2	1309.5	552.5	708.5
Mean	890.5	579.7	446.2	951.0	969.3	953.3	669.8	781.2	1587.1	598.3	918.2	477.0	588.2
SEM	90.4	93.1	52.1	102.0	88.2	90.9	57.3	112.3	253.0	56.2	99.0	50.7	70.6

4.2.3 Rainfall and Temperature Trends Analysis

An analysis of past rainfall trends facilitates an understanding and forecasting of possible future changes, and provides informed and reliable pathways towards adaptation and resilience. Past trends in rainfall, as well as changes in oceanic temperatures, provide important indications about the intensity and frequency of possible future extreme weather events and climate variations (DFED, 2004). This study analyzed observed climatic data for a period covering 58 years (from 1960 to 2018). This facilitated an understanding of the patterns and trends in the climatic variable in the study areas. The process provided the basis for projection of future rainfall changes and patterns. Recorded rainfall data from a total of 16 stations in the districts were used to calculate the average annual rainfall, maximum and minimum temperatures of both districts. The assessed climatic variables were also used to create continuous rainfall and temperature surface maps for the period under consideration through interpolation. The interpolation facilitated the comprehension of the spatio-temporal changes and variations taking place in the study areas. The process facilitated the development of contextualized adaptive measures in each of the study areas. The inverse distance weighting (IDW) interpolation method was used to create the continuous surface heat maps in Geographic Information System (GIS). The IDW interpolation is a widely used method in spatial rainfall distribution studies (Chen & Liu, 2012; Lu & Wong, 2008; Childz, 2004; Watts & Calver, 1991).

4.2.4 Calculation of the Area-Weighted Average Rainfall

The area-weighted average annual rainfall for both districts was obtained through the use of Thiessen's Polygon method. Thiessen's polygon associates each point in an area of interest with the nearest weather station. This procedure tessellates the landscape into zones that are nearer to a specific station than to any other. To calculate the average rainfall values in the created Thiessen polygons over each district, the Thiessen polygons were intersected with the Limpopo Province map through a GIS platform, then the area-weighted averages for each district were determined. The weighted average rainfall associated with each district is calculated using Equation 1 (Garcia *et al*., 2008; Perry & Hollis, 2005) as follows:

$$P_i = \frac{\sum_k A_{ik} P_k}{\sum_k A_{ik}} \qquad \textbf{Equation 4.1}$$

where P_i is the district weighted average rainfall in mm; P_k is the rainfall associated with each weather station in mm; A_{ik} is the area of intersected polygon associated with weather station k and district in m^2.

4.2.5 Evaluation of the climatic moisture index

As already alluded to, the degree of aridity in the Mopani and Vhembe districts was estimated using the Climatic Moisture Index (CMI). The CMI is an index or a numerical indicator of the relative dryness (aridness) or wetness of a particular region, and it represents the water stress or scarcity (aridity). It is calculated from a combination of temperature and precipitation, as well as soil moisture. Thus, there is a close correlation between the CMI and potential evapotranspiration. The CMI is based on the methodology developed by Willmott & Feddema [29], who used the ratio of annual precipitation (P) to annual potential evapotranspiration (PET), as follows:

$$\text{CMI} = \frac{\text{P}}{\text{PET}} - 1, \qquad \text{when P} < \text{PET} \qquad \textbf{Equation 4.2}$$

$$\text{CMI} = 1 - \frac{\text{PET}}{\text{P}}, \qquad \text{when P} \geq \text{PET} \qquad \textbf{Equation 4.3}$$

The CMI indices range from −1 to +1, where wet climatic conditions indicate a positive CMI, and dry conditions indicate a negative CMI. Therefore, the CMI is a cumulative measure of potential water availability, which is dependent exclusively on climate variables [29]. The PET of each district was calculated using observed data from weather stations dotted about the study areas. The calculated results were interpolated to create a continuous PET dataset. Thiessen's Polygon method was beneficial for determining the area-weighted average PET for both districts. The CMI was calculated only for seven years i.e., 1960, 1970, 1980, 1990, 2000, 2010, and 2020 (a decadal interval that shows meaningful changes in rainfall and temperature changes). The results were then used to assess the aridity of the districts. Then the weighted average for both districts was calculated from the interpolated continuous surface using Thiessen's Polygon method. The CMI is used here as relational to climate variability and change taking place in the study area (Nhamo *et al*., 2019).

4.2.6 Statistical Tests

For the statistical data analysis, the 2021 TIBCO STATISTICA Version 14.0.0.15 TIBCO Software (data analysis software system) was utilized. A repeated measures Analysis of Variance (ANOVA) for rainfall, minimum and maximum temperatures as well as CMI were assess for the statistical significance. Statistical regression analysis (ordinary regression) over time was carried out to determine if there was a long-term trend in the average rainfall, minimum and maximum temperatures as well as CMI rainfall over the interval of 1960 to 2018.

4.3 Results and discussion

4.3.1 Rainfall patterns

The usual indicators of climate change (increasing aridity, rising temperatures, the increasing frequency and intensity of droughts, and flooding) have been worsening in the two districts, since 1960 to date (Parry *et al*., 2001). Rainfall over the two districts is strongly seasonal, with the greatest part of the rainfall experienced during the summer from December to February. Rainfall measures of up to 100 mm/month were recorded from December to February. Sometimes the downpours had an early beginning (September/October) and in fewer cases the rainy season may carry over into April.

Figure 4.2 presents the annual average rainfall by season (summer, autumn, winter, and spring) from 1960 to 2018 for the Mopani and Vhembe Districts, Limpopo Province. The summer season (December to February) is shown to be the most humid and the winter (June to August) is the most arid and driest. Autumn (March to May) and spring (September to November) are generally transitional seasons that usher into winter and summer, respectively. From season to season, rainfall is also highly variable and is characterised by inter-seasonal dry periods over the study area (Figure 4.2). Therefore, according to Figure 4.2 it is evident that rainfall is highly variable in the study area with inter-seasonal droughts. The peaks are indication of flooding seasons, and the lows indicate drought. This high variability is unfavourable for rainfed agriculture as the rainfall is unreliable. Therefore, the main challenge in the study area is high climate variability and not necessary climate change.

Departures from mean rainfall additionally show a considerable extent between yearly fluctuations with drier years during the 1990s (Figure 4.2). This gives an impression of being a basic defining moment in rainfall inconsistencies from around 1995. It is demonstrated that the driest year in the time arrangement relates to the 1991/1992 season while the wettest season happened in 2000 due to flooding in that year.

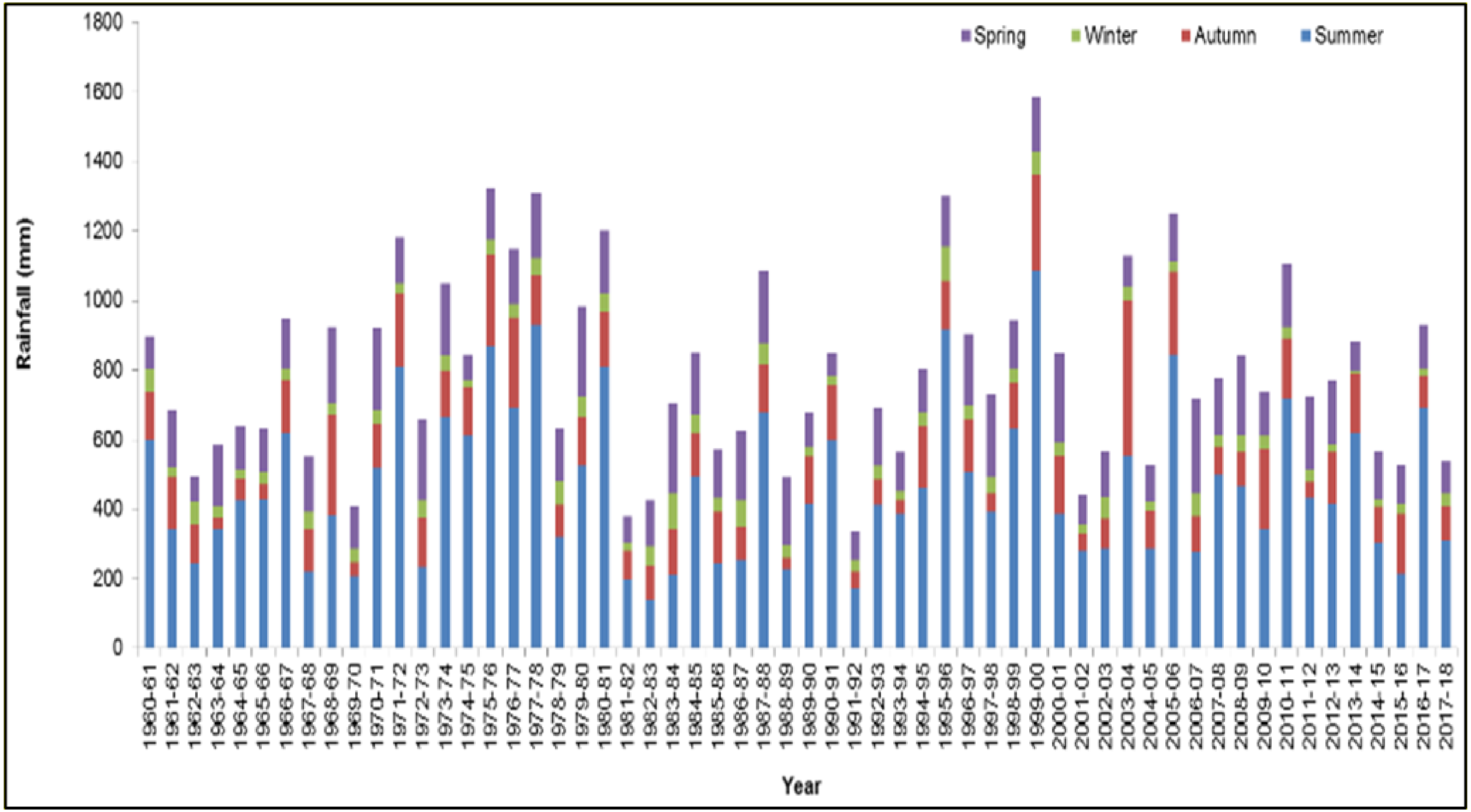


Figure 4.2: Seasonal average rainfall in the study districts indicating high rainfall variability

The spatial distribution of annual rainfall during 58 years from 1960 to 2018 in the Mopani and Vhembe districts is shown in Figure 4.3. The maps were created using Thiessen's Polygon method. The maps show significant changes in rainfall patterns in both districts during the past 58 years. The total annual rainfall has declined significantly during the 58 years under observation. A perusal of Figure 4.3 (2018 map), which represents the rainfall pattern of 2018, indicates that almost the entire Mopani and Vhembe districts' surface area has become arid, receiving less than 350 mm of rainfall, qualifies the districts to be a climate change hot spot zone. The decline in rainfall over the past 58 years has placed the farmers of the Mopani and Vhembe districts in a vulnerable position because of the impacts of climate change.

Table 4.1 presents the average rainfall values of different stations for the Mopani and Vhembe districts, Limpopo Province from 1960 to 2018 at an interval of 5 years, except for the last year. Considering the annual rainfall value of 1960 as the base year, the percentage change in the rainfall values was calculated (Table 4.1). The general pattern of rainfall shown in Figure 4.3 and Table 4.1 indicates that rainfall is highly variable. This is confirmed by a repeated measures ANOVA over time for these districts, which indicated that the average rainfall differed statistically significantly ($F(57,855) = 12.84$; $p < 0.001$) over time (Table 4.2). The pattern shows extreme incidences of floods and droughts as shown by the considerable extent, respectively. Examples of such extreme climatic conditions are the 1962-1966 and 1970/71 moderate droughts, 1982/83, 1991/92, and 2015/16 severe drought [35,36], and the 2000 floods (Mpandeli *et al*., 2019). According to the statistics shown in Table 4.1, rainfall totals in both districts decreased by 38% from 1960 to 2018. The annual average rainfall in both the Mopani and Vhembe districts seemed to decrease between 1960 and 2018, as shown in the maps in Figure 4.3 and the graphs in Figure 4.2. The decrease in the annual rainfall would lead to water scarcity and the occurrence of droughts in the region, which have been more frequent of late. This would place the districts in a very high climate change vulnerable position. However, an ordinary regression analysis over time to determine if there was a long term trend in the average rainfall over the interval of 1960 to 2018 indicated no statistically significant decrease in the rainfall over time (Table 4.3).

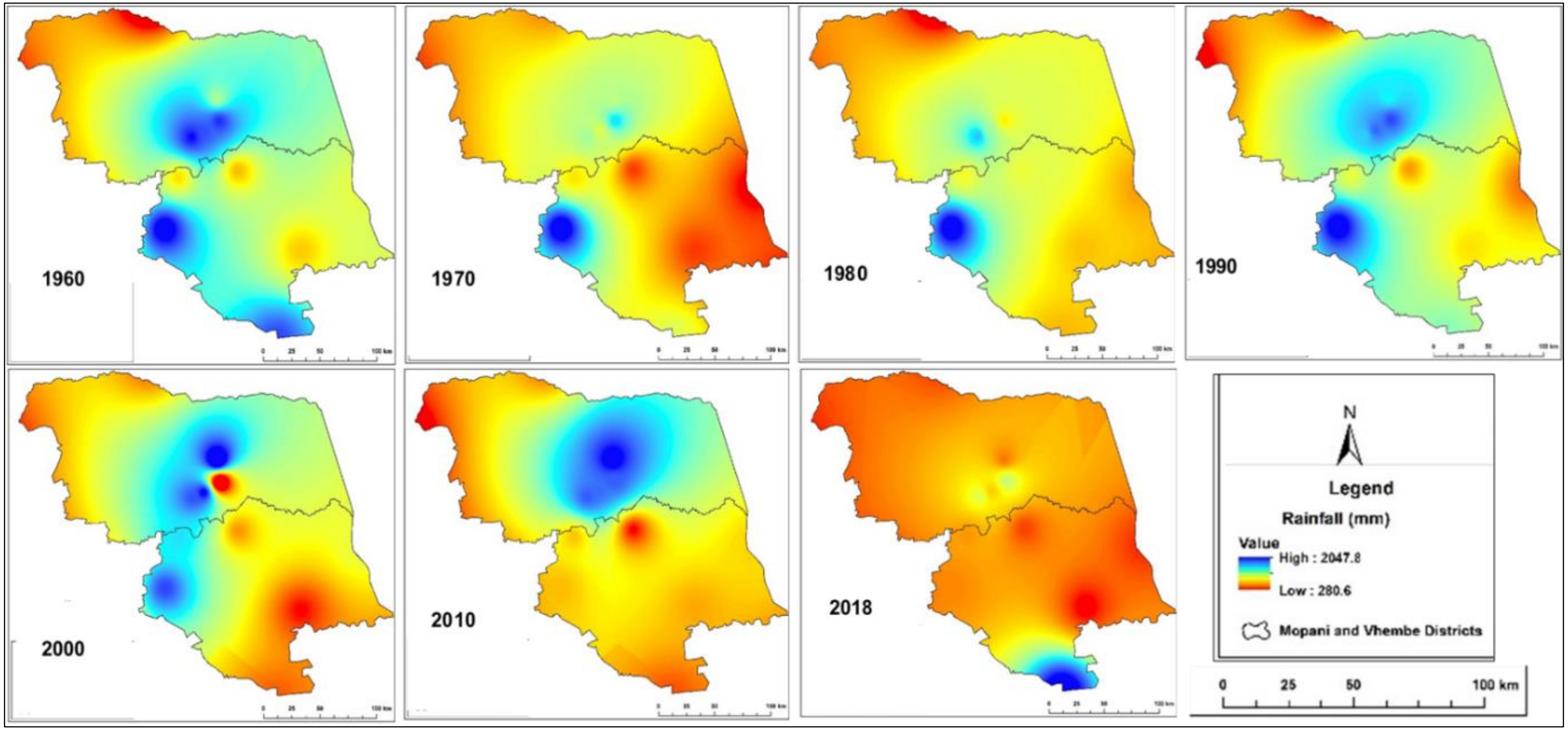


Figure 4.3: Average rainfall for 1960, 1970, 1980, 1990, 2000, 2010, and 2018 in the Mopani and Vhembe districts

Table 4.2: ANOVA for minimum temperature in the Mopani and Vhembe districts

Effect	Repeated Measures Analysis of Variance for Rainfall				
	SS	Degr. of Freedom	MS	F	p
Intercept	472897652	1	472897652	90,66	<0,0001
Error	78241399	15	5216093		
Years	41955379	57	736059	12,84	<0,0001
Error	49011699	855	57324		

Table 4.3: Statistical regression analysis for annual rainfall in the Mopani and Vhembe districts

N = 944	$R^2 = 0.0003$					
	b *	Std. Err. of b *	b	Std. Err. of b	t(942)	*p*-Value
Intercept			1555.82	1619.28	0.96	0.337
Time	−0.017	0.033	−0.42	0.81	−0.52	0.604

4.3.2 Temperature

At the global level, the average surface temperature has risen by 0.6 °C over the last century. Surface temperatures are also projected to rise by between 1.4 to 5.8 °C by 2100 (IPCC, 2007). The analysis in this study is unique in its assessment as it uses more detailed spatial temperature trends, therefore, adding to a significant contribution to the grasping of potential impacts of temperature changes over the area under study.

Table 4.4 presents the average annual minimum temperature values of different stations for the Mopani and Vhembe districts, Limpopo Province from 1960 to 2018 at an interval of 5 years, except for the last year. A repeated measures ANOVA over time for these districts indicated that the average minimum temperature differed statistically significantly ($F(57,855) = 3.55$; $p < 0.001$) over time (Table 4.5). Considering the annual minimum temperature of 1960 as the base year, the percentage change in the minimum temperature values was calculated (Table 4.4).

The general pattern of minimum temperature shown in Figure 4.4 and Table 4.4, 4.5 and 4.6, indicates that the minimum temperature is increasing significantly. Table 3 and 5 shows that the average annual minimum temperature has significantly increased from 13.7 °C to 16.3 °C (2.6 °C) during the 58 years under observation. This is confirmed by the results of an ordinary regression analysis over time to determine if there was a long-term trend in the average minimum temperature over the interval of 1960 to 2018, which indicated a statistically significant increase in minimum temperature over time in with standardized beta = 0.07, so there is a trend for minimum temperature to became significantly higher over time (Table 4.6).

A perusal of Figure 4.4, which represents the minimum temperature of 2018, indicates that increases in the minimum temperature of 3.0 °C and 2.3 °C for the Mopani and

Vhembe districts, respectively, over the 58 years, qualifying the districts to be a climate change hot spot zone. The highest minimum temperature increase (7.6 °C) in the Mopani district was recorded between Greater Giyani and Greater Letaba municipalities, while in the Vhembe district highest minimum temperature increase (3.8 °C) was recorded between Levubu and Tshiombo.

The spatial distribution of average minimum temperature during 58 years from 1960 to 2018 in the Mopani and Vhembe districts is shown in Figure 4.4. The maps in Figure 4.4 were created using Thiessen's Polygon method. The maps show significant changes in minimum temperature patterns in both districts during the past 58 years. The annual minimum temperature has increased significantly during the 58 years under observation. The trends are certainly real, and the warming is large enough to have significant impacts on the hydrology and ecosystems of the districts.

Table 4.7 presents the average annual maximum temperature values of different stations for the Mopani and Vhembe districts, Limpopo Province from 1960 to 2018 at an interval of 5 years, except for the last year. A repeated measures ANOVA over time for these districts which indicated that the average maximum temperature differed statistically significantly ($F (57, 855) = 14.17$; $p < 0.001$) over time (Table 4.8). Considering the annual maximum temperature value of 1960 as the base year, the percentage change in the maximum temperature values was calculated (Table 4.7). The general pattern of maximum temperature shown in Figure 4.5 and Table 4.7, indicates that the maximum temperature is increasing. Table 6, 7 and 8 shows that the average annual maximum temperature has significantly increased from 13.7 °C to 16.3 °C (2.5 °C) during the 58 years under observation (Table 4.7 and 4.8). This is confirmed by the results of an ordinary regression analysis over time to determine if there was a long-term trend in the average maximum temperature over the interval of 1960 to 2018, which indicated a statistically significant increase in maximum temperature over time in with standardized beta = 0,26, so there is a trend for maximum temperature to became significantly higher over time (Table 4.9).

A perusal of Figure 4.5 for the year 2018 indicates that increases in the maximum temperature of 3.20 °C and 1.6 °C for the Mopani and Vhembe districts, respectively over the 58 years, qualifying the districts to be a climate change hot spot zone. The highest minimum temperature increase (11.2 °C) in the Mopani district was recorded between Greater Giyani and Greater Letaba municipalities, while in the Vhembe district highest minimum temperature increase (3.2 °C) was recorded in Musina municipality.

The spatial distribution of average maximum temperature during the 58 years under review (from 1960 to 2018) in Mopani and Vhembe districts is given in Figure 5. The maps (Figure 5) were developed through the interpolation by the inverse of the square of the distances. The maps provide important information on the changes that took place in the maximum temperatures in both districts during the 58 years. The annual minimum temperatures significantly rose during the same period. These results agree with the general knowledge that recognizes the increasing temperatures in Limpopo Province [38]. This information is critical when formulating policies and supporting decision-making on climate adaptation and resilience. The findings in this study are also beneficial for preparedness and risk reduction of extreme weather events. The FAO has stated that rising temperatures and increasing drought frequency and intensity in Southern Africa are the factors most affecting households and crop productivity, compounding household food security in the region. Climate change and variability have made households more susceptible to extreme weather events as the environments continue to degrade, impacting environmental and human health. This evidence of rising temperatures over the Mopani and Vhembe districts has seen shifts in the crop growing season, due to changes in the hydrological cycle.

Table 4.4: The average annual minimum temperature in the Mopani and Vhembe districts

Station	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2018
Grenshoek (Sape)	12.5	15.1	15.0	15.9	13.8	16.0	18.6	17.7	14.9	17.1	17.1	17.2	17.6
Phalaborwa-AER	13.8	11.9	13.9	12.5	16.3	12.5	13.2	13.0	15.5	13.1	13.4	13.3	13.5
Giyani-Amfarm	13.5	14.7	15.3	15.2	15.1	16.0	15.1	15.0	14.2	15.9	14.2	15.0	14.9
Letaba	14.2	15.7	16.2	15.0	15.3	17.0	16.9	16.3	15.9	15.8	15.9	15.8	16.2
Mopani	14.1	15.4	16.2	15.1	15.1	16.1	16.5	16.1	15.7	16.1	15.6	15.6	15.8
Bavaria Fruit Estates	13.3	12.5	13.9	13.7	13.9	14.1	15.3	16.0	15.5	15.4	15.2	14.5	14.9
Mopani: Sekgosese	13.0	14.3	14.6	14.3	14.6	14.2	14.6	13.9	14.3	15.5	16.3	18.2	20.6
Thohoyandou	14.0	15.2	15.9	15.2	15.8	15.5	15.3	15.9	15.1	16.2	16.9	17.1	16.9
Messina Proefplaas	15.1	15.0	15.4	14.8	15.0	15.7	15.4	15.9	16.0	16.2	15.6	15.7	15.7
Levubu (S)	13.7	17.5	18.1	17.2	14.9	18.1	18.2	18.3	14.4	18.9	18.0	17.8	17.4
Venda: Tshiombo	14.1	17.9	18.7	18.0	16.0	17.8	17.9	18.1	14.7	18.6	17.9	18.3	17.8
Venda: Lwamondo	13.8	14.9	15.4	14.6	15.0	15.5	15.2	16.0	15.6	16.3	14.7	14.7	16.3
Mean	13.7	15.0	15.7	15.1	15.1	15.7	16.0	16.0	15.2	16.3	15.9	16.1	16.3
SEM	0.2	0.5	0.4	0.4	0.2	0.5	0.5	0.5	0.2	0.4	0.4	0.5	0.6

Table 4.5: ANOVA for minimum temperature in the Mopani and Vhembe districts

Effect	Repeated Measures Analysis of Variance for maximum temperature				
	SS	Degr. of Freedom	MS	F	p
Intercept	206214,9	1	206214,9	1536,54	<0,0001
Error	2013,1	15	134,2		
Years	180,3	57	3,2	3,55	<0,0001
Error	762,3	855	0,9		

Table 4.6: Statistical regression analysis for minimum temperature in the Mopani and Vhembe districts

N = 944	$R^2 = 0.066$					
	b *	Std. Err. of b *	b	Std. Err. of b	t(942)	*p*-Value
Intercept			0.33	6.77	0.05	0.957
Time	0.07	0.033	0.01	0.003	2.14	0.032

Table 4.7: The average annual maximum temperature in the Mopani and Vhembe districts

Station	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**
Grenshoek (Sape)	26.7	27.0	27.6	26.4	26.1	26.0	25.3	25.4	24.5	27.3	28.5	27.5	28.1
Phalaborwa-AER	27.6	29.8	29.6	28.0	27.7	29.4	29.1	29.2	28.6	29.7	30.8	31.7	30.2
Giyani-Amfarm	27.4	27.2	28.4	27.6	27.6	28.4	26.9	28.5	27.8	27.9	27.3	29.8	29.7
Letaba	28.5	30.8	31.3	27.9	27.4	30.6	30.6	29.7	28.8	29.3	30.0	31.4	30.1
Mopani	28.1	30.1	30.8	27.4	27.1	29.8	30.3	29.7	29.0	29.3	29.4	31.1	30.1
Bavaria Fruit Estates	26.1	26.4	27.4	26.5	27.1	27.8	28.0	28.5	27.6	29.7	28.9	28.8	27.6
Mopani: Sekgosese	27.0	26.9	27.8	26.2	26.3	26.4	26.5	26.3	24.7	27.0	30.4	34.8	38.2
Thohoyandou	27.4	26.6	27.7	25.8	26.1	26.9	27.5	27.3	24.9	28.4	26.9	28.7	29.3
Messina Proefplaas	29.6	29.8	30.7	29.4	29.7	29.5	30.1	30.2	28.6	29.5	29.4	33.6	32.8
Levubu (S)	27.3	26.8	27.9	25.9	25.9	26.2	26.4	26.5	25.1	27.7	27.5	29.2	28.2
Venda: Tshiombo	27.5	26.6	27.7	25.8	26.1	26.7	27.2	27.3	26.5	27.8	27.4	28.3	28.5
Venda: Lwamondo	27.4	26.8	27.9	25.9	26.0	26.2	26.7	27.0	25.6	28.1	28.8	30.2	28.7
Mean	27.6	27.9	28.7	26.9	26.9	27.8	27.9	28.0	26.8	28.5	28.8	30.4	30.1
SEM	0.3	0.5	0.4	0.3	0.3	0.5	0.5	0.5	0.5	0.3	0.4	0.6	0.8

Table 4.8: ANOVA for maximum temperature in the Mopani and Vhembe districts

Effect	Repeated Measures Analysis of Variance for maximum temperature				
	SS	Degr. of Freedom	MS	F	p
Intercept	719347,9	1	719347,9	7964,56	<0,0001
Error	1354,8	15	90,3		
Years	644,2	57	11,3	14,17	<0,0001
Error	682,0	855	0,8		

Table 4.9: Statistical regression analysis for maximum temperature in the Mopani and Vhembe districts

N = 944	$R^2 = 0.066$					
	b *	Std. Err. of b *	b	Std. Err. of b	t(942)	*p*-Value
Intercept			−22.97	6.21	−3.70	0.0002
Time	0.268	0.03	0.03	0.003	8.18	<0.0001

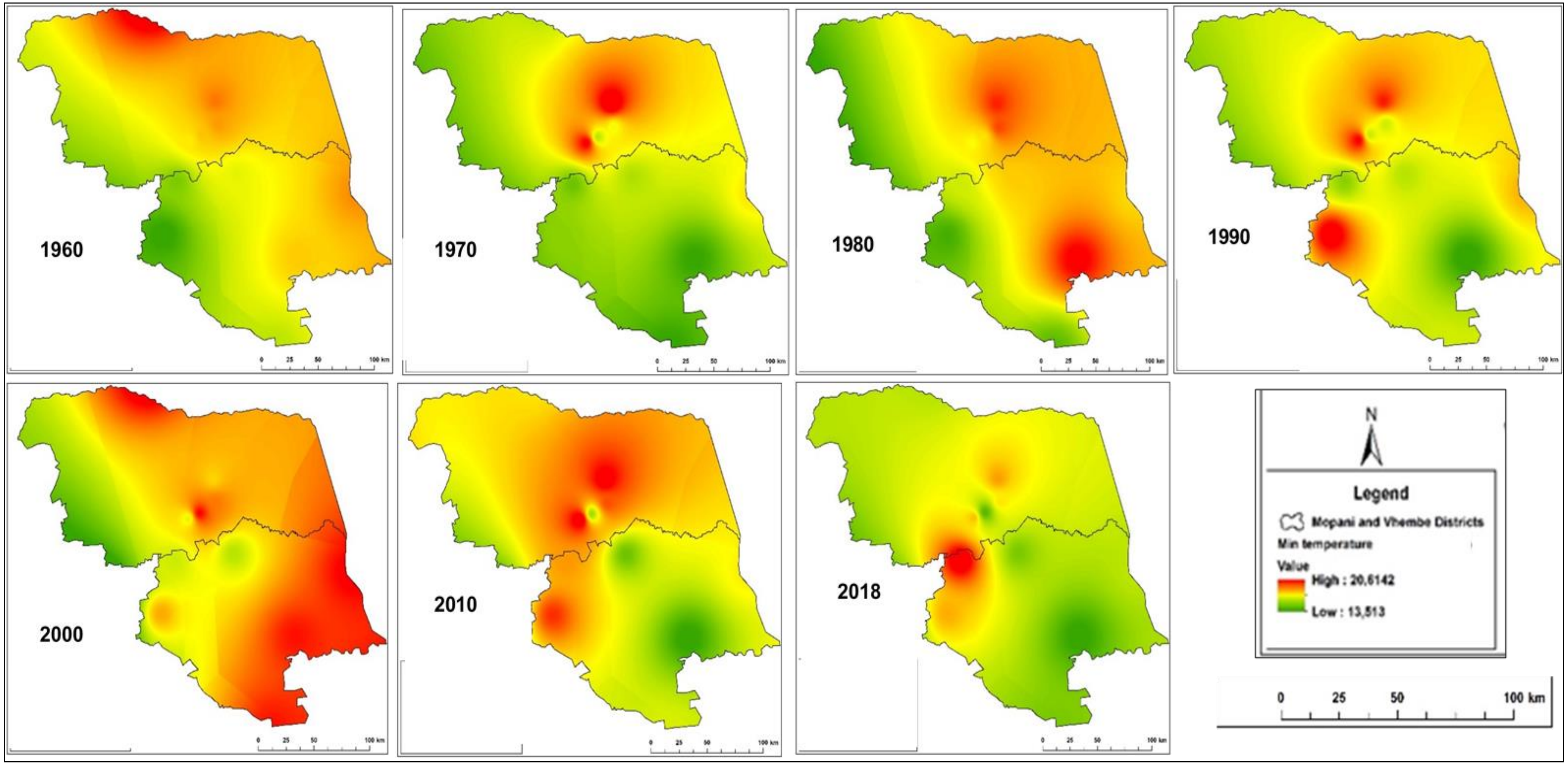


Figure 4.4. Minimum temperature for 1960, 1970, 1980, 1990, 2000, 2010, and 2018 in the Mopani and Vhembe districts

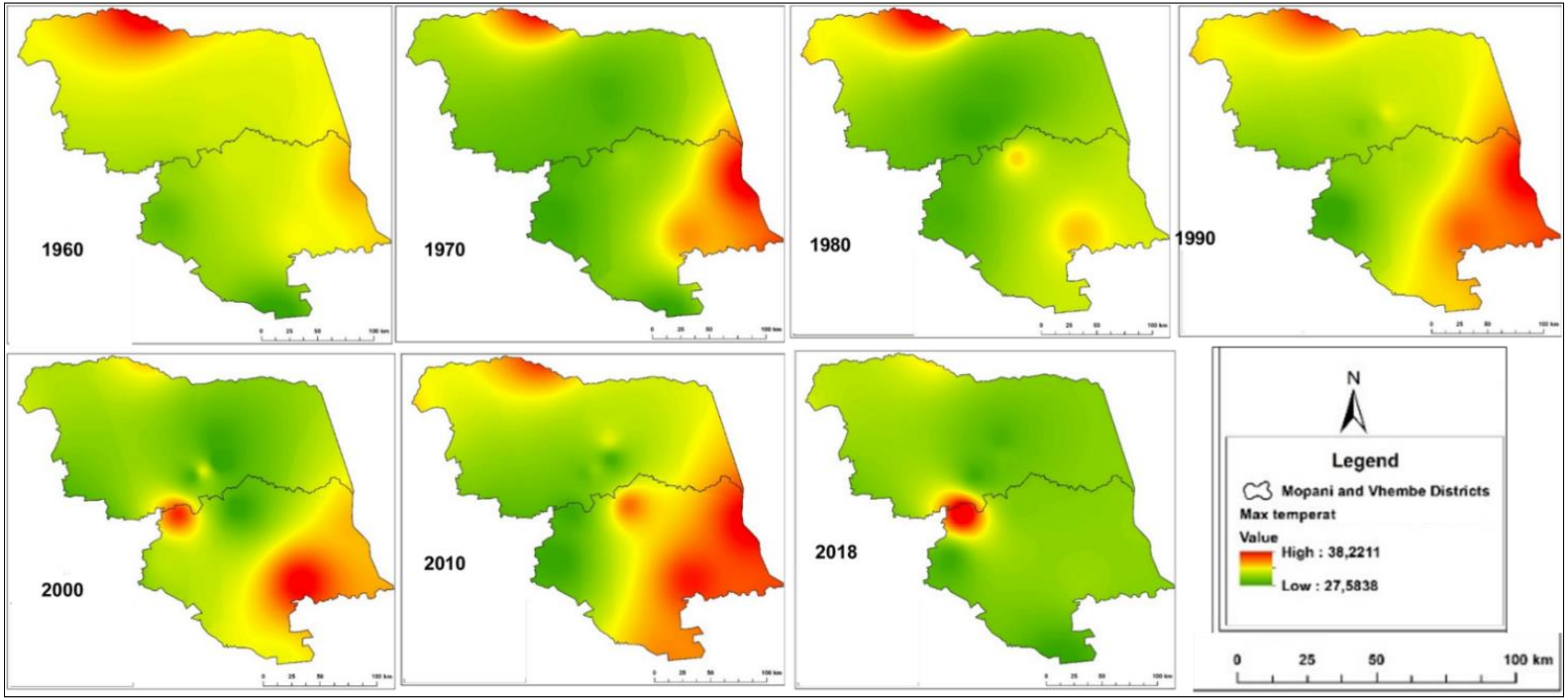


Figure 4.5: Maximum temperature for 1960, 1970, 1980, 1990, 2000, 2010, and 2018 in the Mopani and Vhembe districts

4.3.3 Degree of Aridity and Water Scarcity

Table 4.10 presents the CMI of both the Mopani and Vhembe districts, which are all negative. The CMI was calculated using annual rainfall (P) and annual potential evapotranspiration (PET) applying equations 2 and 3. The negative CMI values indicate that the PET in the region exceeds precipitation. According to Vörösmarty *et al*. (2005), there is a classification link between CMI values and climatic conditions (CMI < −0.6 = Arid; −0.6 ≤ CMI ≤ 0 = Semi-arid; and CMI > 0 = Humid).

Table 4.10: Climatic Moisture Index (CMI) for the Mopani and Vhembe districts

Station	1960	1970	1980	1990	2000	2010	2018
Grenshoek (Sape)	−0.2	−0.5	0.1	−0.3	0.8	−0.5	−0.7
Phalaborwa—AER	−0.6	−0.8	−0.4	−0.7	−0.5	−0.6	−0.8
Amfarm	−0.7	−0.9	−0.6	−0.8	−0.5	−0.8	−0.8
Letaba	−0.7	−0.9	−0.7	−0.8	−0.6	−0.8	−0.8
Mopani	−0.7	−0.9	−0.6	−0.8	−0.4	−0.7	−0.9
Bavaria Fruit Estates	−0.5	−0.8	−0.6	−0.7	−0.5	−0.7	−0.1
Sekgosese	−0.7	−0.8	−0.5	−0.7	0.0	−0.7	−0.8
Thohoyandou	−0.3	−0.6	−0.4	−0.4	−0.9	−0.1	−0.4
Messina Proefplaas	−0.8	−0.8	−0.7	−0.8	−0.4	−0.6	−0.8
L.Trichard: Levubu (S)	−0.5	−0.8	−0.4	−0.6	0.2	−0.4	−0.6
Venda: Tshiombo	−0.6	−0.8	−0.5	−0.6	0.4	−0.3	−0.8
Venda: Lwamondo	−0.5	−0.8	−0.4	−0.6	0.3	−0.5	−0.7
Zebediela	−0.6	−0.8	−0.4	−0.6	−0.5	−0.6	−0.8
Makhado: All Days	−0.7	−0.8	−0.6	−0.9	−0.5	−0.8	−0.9
Polokwane: mmondale	−0.8	−0.8	−0.6	−0.7	−0.5	−0.7	−0.8
AL3 Boerdery	−0.8	−0.9	−0.6	−0.7	−0.6	−0.7	−0.8
Average	−0.6	−0.8	−0.5	−0.7	−0.3	−0.6	−0.7

The average CMI for both districts over the years under observation was calculated as −0.70, qualifying the region to be a dry and water-scarce area according to the Vörösmarty *et al*. (2005) classification. A repeated measures ANOVA over time for these districts indicated that the average CMI differed statistically significant over time ($F(57,855) = 9.37$; $p < 0.001$), (Table 4.11).

Table 4.11: ANOVA for Climatic Moisture Index (CMI) in the Mopani and Vhembe districts

Effect	Repeated Measures Analysis of Variance for CMI				
	SS	**Degr. of Freedom**	**MS**	**F**	**p**
Intercept	340,62	1	340,62	149,38	<0,0001
Error	34,20	15	2,28		
Years	19,32	57	0,34	9,37	<0,0001
Error	30,92	855	0,04		

The aridness of both districts seemed to increase over the years making the districts a water-scarce area (Figure 4.6). This is not an encouraging sign for agriculture, where water plays a crucial role as input to the production system. This will have a more negative impact on rain-fed agriculture’s production and productivity. The large-scale implementation of various water harvesting techniques will also go a long way in alleviating water scarcity and low crop productivity. Therefore, a steady and sustainable effort should be made to bring more arable land under irrigated conditions. However, an ordinary regression analysis over time to determine if there was a long-term trend in the average CMI over the interval of 1960 to 2018, indicated that there was no statistically significant decrease in the aridness over time (Table 4.12).

Table 4.12: Statistical regression analysis for CMI in the Mopani and Vhembe districts

N = 944	$R^2 = 0.066$					
	b *	Std. Err. of b *	b	Std. Err. of b	t(942)	*p*-Value
Intercept			−1.69	1.14	−1.48	0.138
Time	0.031	0.033	0.001	0.001	0.95	0.340

Although not statistically significant, the CMI of the study area seems to indicate a worsening aridity is indicative of the adverse climatic conditions, which are not favorable to rain fed areas that dominates smallholder agriculture in the area. There is an urgent need to adopt modern farming technologies and the use of new seed hybrids and grow under-utilized indigenous crops that are adapted to the local conditions. Another adaptation strategy is the introduction of solar irrigation to tap the groundwater resources to enhance crop water productivity and create employment, as with irrigation there is cultivation throughout the year.

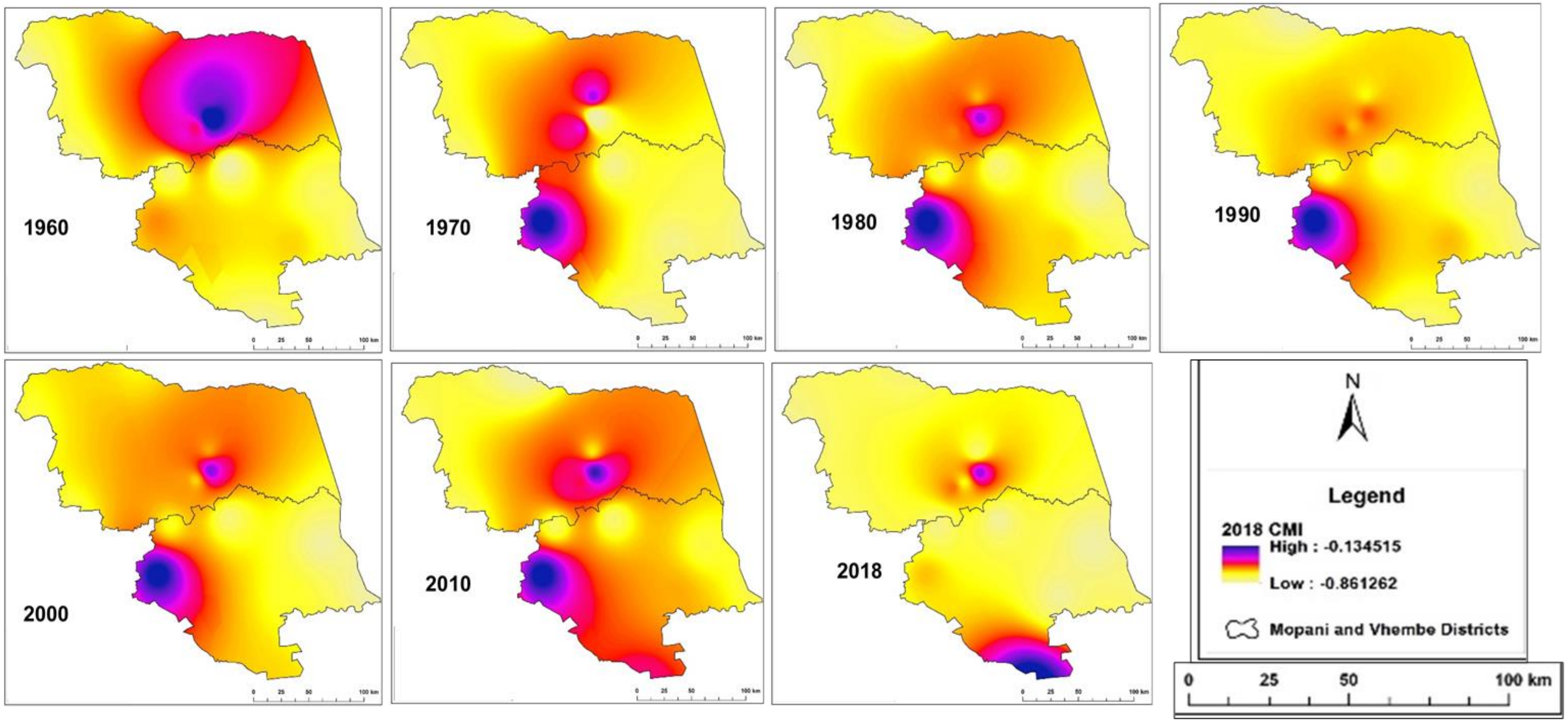


Figure 4.6: Climatic Moisture Content (CMI) for 1960, 1970, 1980, 1990, 2000, 2010, and 2018 in the Mopani and Vhembe districts

4.3.4 Correlation between Rainfall Variability, Aridity and Cereal Production

The variations in moisture in the study area adversely causing reduced crop productivity due to worsening aridity (Figure 4.7). Rainfed agriculture, coupled with other factors such as poor infrastructure and lack of resources to adapt to the changing environment, are only compounding the vulnerability of the two districts under study. These changes are projected to result in a reduction of between 2% and 7% in agricultural GDP by 2100 (Nhamo *et al*., 2019; IPCC, 2001). Although rainfall has been mainly highly variable from 1960 to 1978, it started to decline since then and to date. Although cereal production has been increasing steadily over the years, it has always failed to meet the demands of a growing population (Nhamo *et al*., 2019). The lows in cereal production coincide with seasons of droughts.

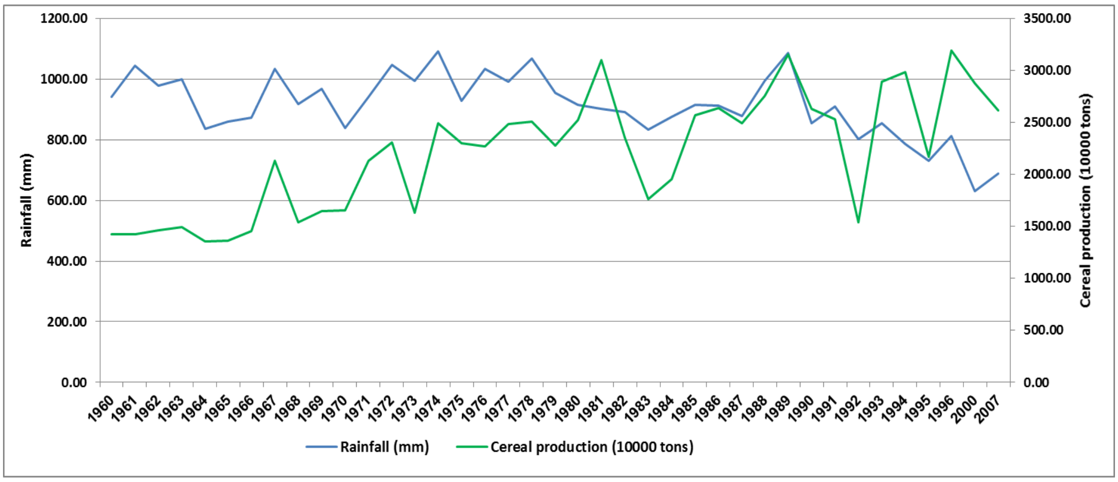


Figure 4.7: Correlation between rainfall variability and cereal production in southern Arica over time as influenced by increased aridity

4.4 Recommendations

There is a need to intensify irrigation by using the vast and untapped groundwater resource, as dependence on rainfall is highly unreliable due to occurrences of droughts and floods. The large-scale implementation of various water harvesting techniques will be a sustainable approach in alleviating water scarcity and low crop productivity. Resources should now be channeled towards adaptation and building resilient communities. One systematic, transformative, and integrated approach that is being spearheaded to guide policy and decision-making to develop informed adaptation strategies is the Water–Energy–Food (WEF) nexus, a polycentric approach that considers all resources in equal terms and is a decision support tool to mitigate trade-offs and maximize on synergies. Unlike the Integrated Water Resources Management (IWRM) that is water-centric, the WEF nexus is multi-centric, promoting cross-sectoral resource management. Sectoral approaches in resource management only transfer challenges to other sectors as each sector pursues its strategies and policies. However, the WEF nexus stimulates stakeholder engagement before the implementation of any developmental project. Table 4.13 provides some of the adaptation strategies that can be adopted to increase the resilience of smallholder farmers to the impacts of climate change.

Table 4.13: Context-based adaptation strategies in Mopani and Vhembe Districts

Climate Change Impact	Recommended Adaptation Strategy
Shortened rain season (Starting around December and ending in March)	• Provide access to agro-meteorological information and services • Mainstreaming weather information into agricultural extension support using social media • Plant early maturing under-utilized crop varieties that adapt to local hash conditions • Crop diversification and intercropping • Ex- and in-situ rainwater harvesting and conservation techniques
Intra-seasonal dry spells during the cropping season	• Adopt a crop diversification system • Construct small water reservoirs in support of ex- and in-situ rainwater harvesting • Adopt water conservation technologies (mulching, ridging, etc.) and employ limited tillage to conserve soil water
Increasing temperatures and heatwaves	• Breed heat-tolerant livestock and encourage destocking during drought periods • De-bushing for rangeland rehabilitation • Invest in smallholder fodder production and distribute drought-resistant seeds • Provide additional feeding for cattle • Encourage the rearing of small stock production • Promote the cultivation of under-utilised and small grains, e.g., sorghum and millets • Promote mulching to conserve to reduce erosion and lower soil temperature • Promote and encourage intercropping
Increased frequency and intensity of droughts	• Access to early warning services throughout the year and especially during the cropping season • Crop diversification through intercropping, market gardening, etc. • Promote modern technologies like weather-based index-insurance • Stone bunds & terracing for runoff mitigation • Adopt modern water conservation practices (e.g., 30%+ mulching, crop, etc.) • Adopt contour planting to enhance infiltration and drainage
Intra and inter-seasonal rainfall variability	• Use of climate-smart agriculture methods • Use social media to reach smallholder farmers with climate information and services • Diversify crop and livestock systems to reduce risk and vulnerability
Increased risk of flooding- (flash floods/cyclones) from January to March	• Enhance access to weather information in near real-time • Mainstreaming weather forecasts into extension services • Enhance disease surveillance through modern technologies and predict pests and diseases • Agro-forestry for increased water capture • Stone bunds and terracing for runoff mitigation

(Adapted from Mpandeli *et al*., 2019)

4.5 Conclusion

Historical annual rainfall data for the past 58 years (1960–2018) was used to analyse the patterns, variability, and trends. This helps in understanding how the rainfall may change in the future. Although not statistically significant, a decline in rainfall amount over the years with more variability in recent years was observed. A decrease in annual rainfall would result in a decrease in annual runoff volumes. Thus, to ensure food security in the districts, there is an urgent need to bring more area under irrigation to have climate-resilient agriculture. The CMI indicates the soil moisture regime is also observed to be declining, although not statistically significant. The soil water regime of both districts regarding crop production is evidenced from the CMI values, which indicate that the area is becoming soil moisture scarce. The analysis also shows that both districts are climate change hot spot areas, highly vulnerable to the impacts of climate change. The increase in temperature and the decrease in the annual rainfall is leading to water scarcity and the occurrence of droughts in the districts, which have been more frequent of late. The analysis data from 1960 to 2018 demonstrated an increased recurrence of drought, as with rainfall variability, which leads to water scarcity and food insecurity. Major climate change impacts in the districts under study are being felt through water resources, thereby affecting all sectors.

CHAPTER FIVE

ASSESSING THE ADAPTIVE CAPACITY OF SMALLHOLDER FARMERS TO CLIMATE CHANGE IN THE MOPANI AND VHEMBE DISTRICTS USING OBSERVED DATA

Part of this chapter will be submitted for publication in the Agriculture Journal

Abstract

Declining rainfall totals and rising frequency and intensity of droughts, floods, and heat waves are signs of the effects of climate variability and change. Due to their limited potential for adaptation and heavy reliance on natural systems for survival, smallholder farmers in poor nations are being particularly impacted by these environmental changes. Although there are general adaptation tactics, they must be adapted to local scales. The Standardised Precipitation Index (SPI) and Standardised Precipitation Evapotranspiration Index (SPEI) were used in this study to evaluate rainfall, temperature, and water stress patterns over time in the Vhembe and Mopani districts of Limpopo Province. To evaluate climate fluctuations, data on temperature and rainfall observations were collected between 1960 and 2018. According to the findings, there has been a noticeable increase in the frequency and severity of droughts, as well as a decrease in rainfall totals and an increase in summertime temperatures. Long-term climate changes serve as a foundation for the creation of specialised adaptation measures. The Vhembe and Mopani districts are at risk from climate change since smallholder farming and rain-fed agriculture account for 81% of the district's cultivated land. As climate change severity varies over time and space, different adaption techniques are used depending on exposure and intensity. Observed meteorological data are essential for creating tailor-made adaptation strategies.

Keywords: agriculture, drought; smallholder farmers; adaptation; climate change; and resilience.

5.1 Introduction

Climate change is the greatest threat to humanity because of the increased frequency and severity of extreme weather events including droughts, floods, heat waves, and cyclones that are occurring today (Shikwambana & Malaza, 2022; Shikwambana *et al*., 2021; Mpandeli *et al*., 2019). Shifting weather patterns that affect agricultural systems and rising sea levels that increase the risk of flooding are both very concerning. Without immediate action to reduce greenhouse gas emissions, the primary driver of global warming, it will be more difficult and expensive to adapt to these repercussions in the future, with potentially disastrous results (Shikwambana & Malaza, 2022; Nhamo *et al*., 2019c; UNGA, 2015). For instance, global agricultural systems have already been impacted by climate change, which has resulted in a 1-5% drop in agricultural production over the past 30 years (Niang *et al*., 2014; Porter *et al*., 2014). If no steps are taken to lower greenhouse gas emissions to tolerable levels, the trend is expected to continue.

Southern Africa is expected to suffer the most from climate change because 60% of its people live in rural, underserved areas and depend on rainfed agriculture and natural systems for their livelihoods (Nhamo *et al*., 2019c). The region is exposed to the whims of climate change and other vulnerabilities when it relies heavily on these climate-sensitive sectors. Given that agriculture accounts for 17% of regional GDP (which rises to almost 28% when middle-income nations are omitted) and 13% of total export value, declining agricultural productivity is having a significant negative economic impact (Niang *et al*., 2014; SADC, 2015).

Southern Africa's agricultural production is being negatively impacted by climate change-induced alterations in different agro-ecological zones since some crops can no longer thrive in the region's harsh climate (Mabhaudhi *et al*., 2019). Communities must change to adapt to these changes in the environment. Each community typically has its own coping and adaptation mechanisms up until the point at which it is strained to the breaking point and would require outside support (Tripathi & Mishra, 2017; Nhamo & Chilonda, 2012). However, adaptation varies from place to place depending on socioeconomic and geographic factors.

Policy makers prefer customised solutions that are viable per geographic location because global adaptation strategies suggested in research do not always work at the community or local level (Nguimalet, 2018; Nkoana *et al*., 2018). To develop tailored adaptation strategies for individual communities, decision-makers must examine and identify the socio-economic and geographic aspects at the local level (Nhamo &

Chilonda, 2012). In order to evaluate vulnerability and the effects of shocks at the household and community levels, the Household Economic Approach (HEA) has been widely employed; however, it is typically an expensive and time-consuming process (Holzmann *et al*., 2008). However, designing smallholder farmers' interventions, coping mechanisms, and adaption strategies at the local level can be done quickly and affordably by using historical climatic data to assess the implications of climate change.

Agro-ecological zones are shifting due to climate change, which has an impact on agricultural productivity by altering rainfall patterns and seasons (Davis & Vincent, 2017). According to Davis & Vincent (2017), some obvious climatic changes include increased evapotranspiration, heatwaves brought on by rising temperatures, and an increase in the frequency and severity of droughts. According to Nhamo *et al*. (2019c), the changes are having an impact on the production of specific crops that do not thrive in the harsh climate. They are also a source of the expansion of pests and diseases, reduced crop yields, and a change in the ideal growing seasons and places. The problem necessitates quick action, especially in developing nations, to increase resilience and decrease susceptibility, primarily in the agricultural sector through a time series study of both remotely sensed and observed data.

Impacts and reactions to climate change vary depending on factors such as sensitivity levels, capacity for adaptation, intervention mechanisms, the effectiveness of available early warning systems, governance and institutional setups, and scenario planning techniques. Using climatic data that was really seen, this study evaluated how the climate changed over time in the Vhembe and Mopani districts, Limpopo Province. The analysis made it possible to comprehend the difficulties experienced by the smallholder farmers, which made it possible to create context-specific adaptation methods for the area. The objective was to build resilience while supplying policy and decision makers with data on coping and adaptive measures at the local level. According to projections made by climate change, the amount of agricultural land in the country will drop by about 15% (Cai *et al*., 2017).

Barriers impacting smallholder farmers from adopting smart climate change technologies are prolonged dry spells, excessive degrees of rainfall variability, and excessive weather-related risks such as floods, droughts, hailstorms, and frosts. The prevalence of these risks has been seen as a shift toward delayed onset and early cessation of rainfall, which has led to a shorter growing season and an increase in the frequency of mid-season dry spells, droughts, and floods, all of which are anticipated to become more frequent and more intense due to predicted climate change.

5.2 Materials and methods

5.2.1 Study area

The Limpopo Province's Vhembe and Mopani districts were the subject of the study (Figure 5.1). These two districts offer the biggest threat, per the province's assessment of climate change (Shikwambana *et al*., 2021; Nhamo *et al*., 2019; Mpandeli *et al*., 2019).

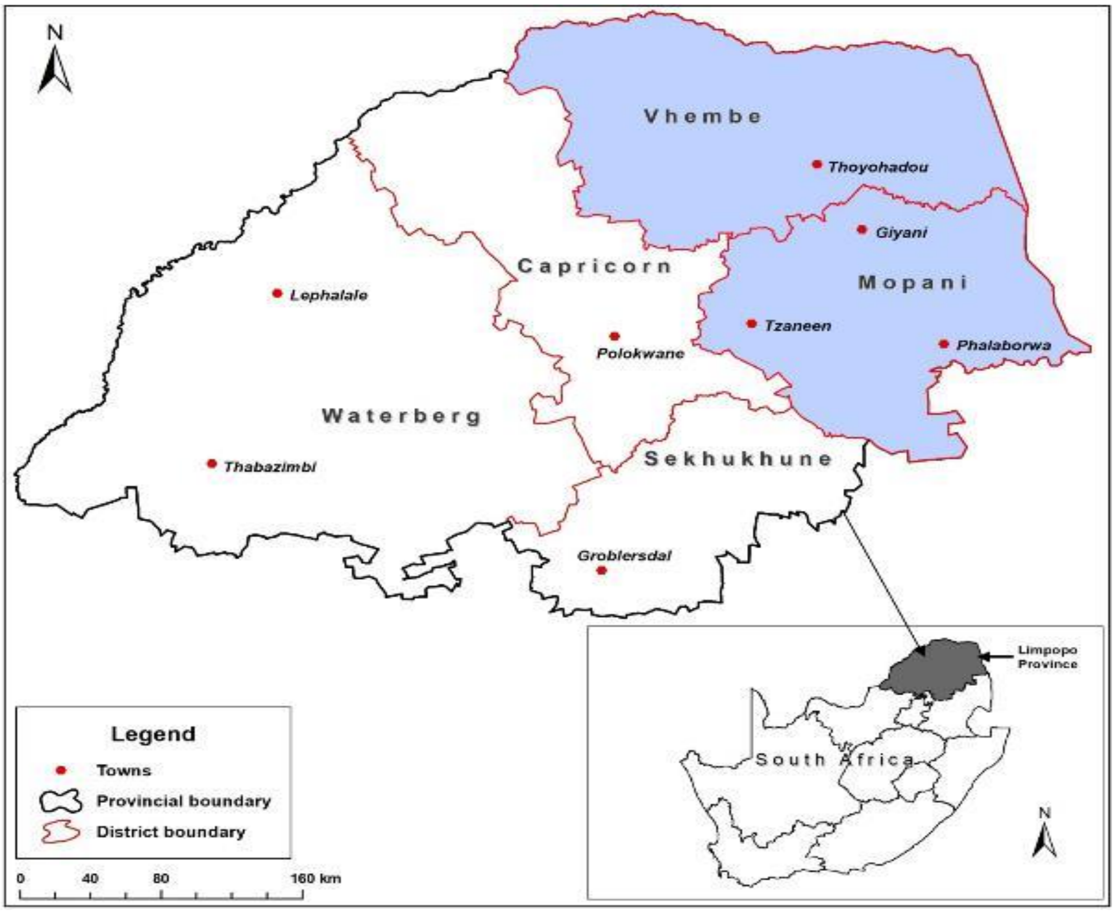


Figure 5.1: The Mopani and Vhembe districts in the Limpopo Province

(Adapted from Shikwambana *et al*., 2021)

The Vhembe district Municipality, which is made up of the local governments of Musina, Collins Chabane, Thulamela, and Makhado, is situated in the northern part of the province of Limpopo and has a total area of approximately 25 597 km^2 (Stats SA, 2015). The Mopani district Municipality is made up of the local governments of Greater Tzaneen, Greater Giyani, Letaba, Maruleng, and Ba-Phalaborwa are all included in the district and has a total land area of about 1 437 734 hectares (IDP, 2012).

The average maximum temperature in the districts varies from 21 to 37 degrees Celsius in January, the average minimum temperature varies from 5 to 12 degrees Celsius in

July, and the average annual temperature ranges from 13 to 27 degrees Celsius (LDA, 2005). Being the hottest month of the year, January, excessive heat is a concern. The district does not see many issues with frost because July is frequently cooler than other months. Its semi-arid climate is marked by hot and humid summers and cold and dry winters. Without the effects of climate change, the winter season lasts from May to September, while the rainy season (summer) lasts from October to April (Cai *et al*., 2017). The months with the highest average temperatures are January (23 °C) and the lowest, June (13 °C). The district's mean annual rainfall varies from 300 mm in the north to 1 000 mm in the south. In January and February, when flooding occurs most frequently, there is the most rainfall (Mpandeli, 2014).

The Vhembe and Mopani districts, like the rest of the province, are rich in agricultural resources (Cai *et al*., 2017; Oni *et al*., 2012). Water resources, however, are a constraint on the agricultural potential's realisation. The district has a limited supply of water resources due to the semi-arid climate and lack of a primary water source (Mashamba, 2008). Average household water use in Limpopo Province is roughly 25 L per person per day, which equates to less than 10 m^3 per person per year (Tshikolomo *et al*., 2012). This shows the extreme level of water shortage in the province. Only 19% of the land is irrigated, while 81% of the land is used for agriculture (Cai *et al*., 2017; Nhamo *et al*., 2018).

The majority of the population lives in rural areas, with agriculture serving as the primary economic sector (DAFF, 2016; Mostert *et al*., 2008). Smallholder farmers make up the majority of the districts and have a land tenure of only about 2 ha (Graeub *et al*., 2016). These farmers face several difficulties, such as limited access to markets, a lack of collateral to obtain financial support from banks, a lack of storage facilities, outdated equipment, poor roads, a high incidence of crop pests like the autumn armyworm (*Spodoptera frugiperda*) on maize and sorghum and the leaf miner (*Tuta absoluta*) on tomatoes, recurring droughts and other extreme weather events, vandalism, poor access to agro-meteorological information, unreliable energy, small land tenure, among others (van Koppen *et al*., 2017).

5.2.2 Data collection

Climatic station data were obtained from the Agricultural Research Council (ARC, 2020) and the South African Weather Service (SAWS, 2020). The data comprised of monthly precipitation, and minimum and maximum temperature for the period 1960 to 2018 on the 10 selected weather stations representing the Mopani and Vhembe district municipalities (Table 5.1). The data underwent a thorough examination to ensure quality and any missing values were patched through the ARC stand-alone Data Patch tool. This procedure involved the combination of Multiple Linear Regression (MLR) and Inverse Distance Weighting (IDW) methods, with data from nearby weather stations (Shabalala & Moeletsi, 2015).

Table 5.1: Information on the 10 selected weather stations representing Mopani and Vhembe district municipalities

District Municipality	Weather station	Latitude (°S)	Longitude (°E)	Altitude (m)
Mopani	Tzaneen	-23.77	30.07	995
	Hoedspruit	-24.42	30.87	550
	Giyani	-23.33	30.65	450
	Sekgosese	-23.38	30.18	670
	Phalaborwa	-23.93	31.15	433
Vhembe	Thohoyandou	-22.97	30.50	600
	Musina	-22.23	29.92	505
	Levubu	-23.08	30.28	610
	Tshiombo	-22.80	30.48	650
	Lwamondo	-23.04	30.37	648

5.2.3 Data analysis

The study employed the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI) as drought identification indices. These indices were chosen due to their widespread adoption by multiple scholars across various geographical regions (Smakhtin & Hughes, 2004). The adaptability of these indices to different time scales was an additional benefit, allowing for calculations to be performed at various points during the agricultural growing season. While the SPI relies solely on rainfall data, requiring less extensive input data and computational effort, it may not comprehensively capture all aspects of agricultural drought. Therefore, the SPEI was included to address drought conditions related to the climatic water balance (Vicente-Serrano *et al*., 2010).

To compute SPI and SPEI, the study utilized the R package SPEI version 1.8.1 (Bergueria & Vicente-Serrano, 2023) on R software. The package implements the methodologies given by McKee *et al*. (1993) and Vicente-Serrano *et al*. (2010) for SPI and SPEI, respectively. The process began with the preparation of input data, which included monthly precipitation, and minimum and maximum air temperature. However, the SPI is based only on precipitation, which is fitted to a probability distribution and then transformed into a normal distribution to give a mean of zero (McKee *et al*., 1993). To calculate the SPI, the following formula introduced by (McKee *et al*., 1993) was utilized:

$$SPI = \frac{X_i - \bar{X}}{S_x}$$ **Equation 5.1**

X_i : Monthly precipitation

S_x : The average precipitation on the time scale

S_x : Standard deviation of precipitation on a time scale

For the calculation of the SPEI, which is based on the difference between precipitation (P) and potential evapotranspiration (PET), the Hargreaves method was applied to estimate PET by utilizing minimum and maximum air temperature. Therefore, a monthly climatic water balance (D) was calculated to measure of water deficit or surplus and then fitted to a probability distribution following the same method of obtaining SPI values. The method for determining SPEI is as follows (Vicente-Serrano *et al*., 2010):

$$D = P - PET$$ **Equation 5.2**

D : Climatic water balance

P : Precipitation

PET : Potential evapotranspiration

The indices were computed over a 3-month timescale, covering both October to December and October to March. This approach was crucial as it provided an indication of the probable impacts of drought on agriculture. Specifically, the 3-month interval offered an indication of soil moisture and crop stress during the season, while the 6-month period was considered capable of effectively reflecting the overall dryness level throughout the season (FAO, 2016). Subsequently, the SPI and SPEI values were interpreted based on the standardized classification system, as outlined by the categories in Table 5.2.

Table 5.2: Drought classification for SPI and SPEI

SPI and SPEI values	Interpretation
+2 and more	Extremely wet
+1.5 to +1.99	Severely wet
+1.0 to +1.49	Moderately wet
+0.99 to -0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

(Adapted from McKee *et al.*, 1993)

5.2.4 Trends analysis

To detect the variable trends in droughts, the non-parametric Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975; Hirsch & Slack, 1984; Pettitt, 1979) was conducted at α (0.05) significance level. The calculation of the test statistic S follows the formula given by:

$$S = \sum_{j=1}^{n-1} \sum_{i=j+1}^{n} sign\left(x_i - x_j\right) \qquad \textbf{Equation 5.3}$$

Where x_i is the SPI / SPEI value at time i, and n is the length of the dataset. The sign function was computed as:

$$sign\left(x_i - x_j\right) = \begin{cases} 1 & if\ \left(x_i - x_j\right) > 0 \\ 0 & if\ \left(x_i - x_j\right) = 0 \\ -1 & if\ \left(x_i - x_j\right) < 0 \end{cases} \qquad \textbf{Equation 5.4}$$

For n > 10, the test statistic Z can be approximated to closely follow a standard normal distribution:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S-1}{\sqrt{Var(S)}} & if\ S < 0 \end{cases} \qquad \textbf{Equation 5.5}$$

Where $Var(S)$ is the variance of statistic S. A positive value of Z specifies and increasing trend while a negative value specifies a decreasing trend. Thereafter, if the data revealed any trend, its magnitude was calculated as follows:

$$\beta = Median\left(\frac{x_i - x_j}{i-j}\right), \forall j < i \qquad \textbf{Equation 5.6}$$

Where x_i and x_j are data values at time t_i and $t_j (i > j)$, respectively.

The null hypothesis for this test assumes that a dataset related to a generic variable doesn't reveal any trend. When the *p*-value of the standardized statistic Z exceeds the chosen significance level, the null hypothesis will be rejected. For this study, the null and alternative hypotheses were defined as:

- H0: the values for SPI and SPEI follow a particular distribution.
- HA: the values for SPI and SPEI do not follow a particular distribution.

The frequencies of drought and wet conditions within the SPI and SPEI datasets were systematically assessed. This analysis aimed to provide information into the historical climate patterns that affected agricultural production in the study region. To categorize the SPI and SPEI values, the values below zero were classified as "Drought" conditions, indicating periods characterized by water deficit. While values equal to or above zero were chosen as "Wet" conditions, signifying periods characterized by sufficient water availability.

Subsequently, the study calculated the number of years falling into each of these two categories to determine the frequency of occurrence. Following this step, the percentage of years corresponding to each category, represented as a proportion of the total number of years within the dataset was derived. This percentage was computed using the formula:

$$Frequency\ percentage = \left(\frac{Count\ of\ category}{Total\ count}\right) \times 100 \qquad \textbf{Equation 5.7}$$

Where:
Frequency percentage = the percentage of a specific category (e.g., "Drought" or "Wet").
Count of category = the number of years categorized under the specific condition
Total count = the total number of years in the dataset.

5.3 Results and discussion

5.3.1 Occurrence of short-term drought conditions (3-month)

This short-term timescale gives an indication of drought conditions that may occur before planting, thus causing delays during the critical stages of crops during the growing season, resulting in crop failure. The frequency of drought was higher on SPI and lower on SPEI (Figure 5.2), which implies that due to the inclusion of PET when calculating SPEI, there rainfall deficiency did not result in drought due to sufficient soil moisture. The average difference between SPI and SPEI for the Mopani district is 21% (Figure 5.2). The drought percentage for Mopani District ranges between 47-52% over the period of 1962-2018.

Before 1990, drought was not as frequent but after 1990, when it is occurring with much intensity and severity (Figure 5.2d). No trend means that the region is not experiencing a change in terms of getting drier or wetter, however, due to climate projections that temperature will rise in the province or region (Shikwambana *et al.*, 2021), evapotranspiration demand might rise, thus there will be insufficient moisture in the soil to counter the effects of short-term rainfall deficiency. The 2015/16 drought was not as extreme in Hoedspruit (Figure 5.2d) as compared to Phalaborwa (Figure 5.2c). This could be due to a number of factors such as prolonged dry spells, high levels of rainfall variability, and farm management. This means that when drought occurs, the drier areas are more susceptible to experiencing severe conditions as opposed to other areas.

The frequency of drought was higher on SPI and lower on SPEI (Figure 5.3), it implies that due to the inclusion of PET when calculating SPEI, there rainfall deficiency did not result in drought due to sufficient soil moisture. The average difference between SPI and SPEI for the Vhembe district is 19% (Figure 5.3). The drought percentage for Mopani district ranges between 44-48% over the period of 1962-2018.

Although there is little difference in the drought percentage between the Mopani and Vhembe districts, both areas are vulnerable to drought. There is high variability of rainfall in both the Mopani and Vhembe districts resulting in a high fluctuation between extreme wet and extreme dry seasons, signifying the vulnerability of smallholder farmers in the study area. This study finds that the increased recurrence of droughts in the districts is related to El Niño. Drought seasons were observed to be related to high dry spell frequencies. An analysis of rainfall variances by season demonstrated that drought tends to be widespread in the two districts. However, no drought is similar to another drought, with critical heterogeneity in the intensity of drought over the area. The frequency analysis of drought given by the SPEI revealed that for the emergence and early vegetative stage, a high risk of frequent droughts was observed following planting in November-December.

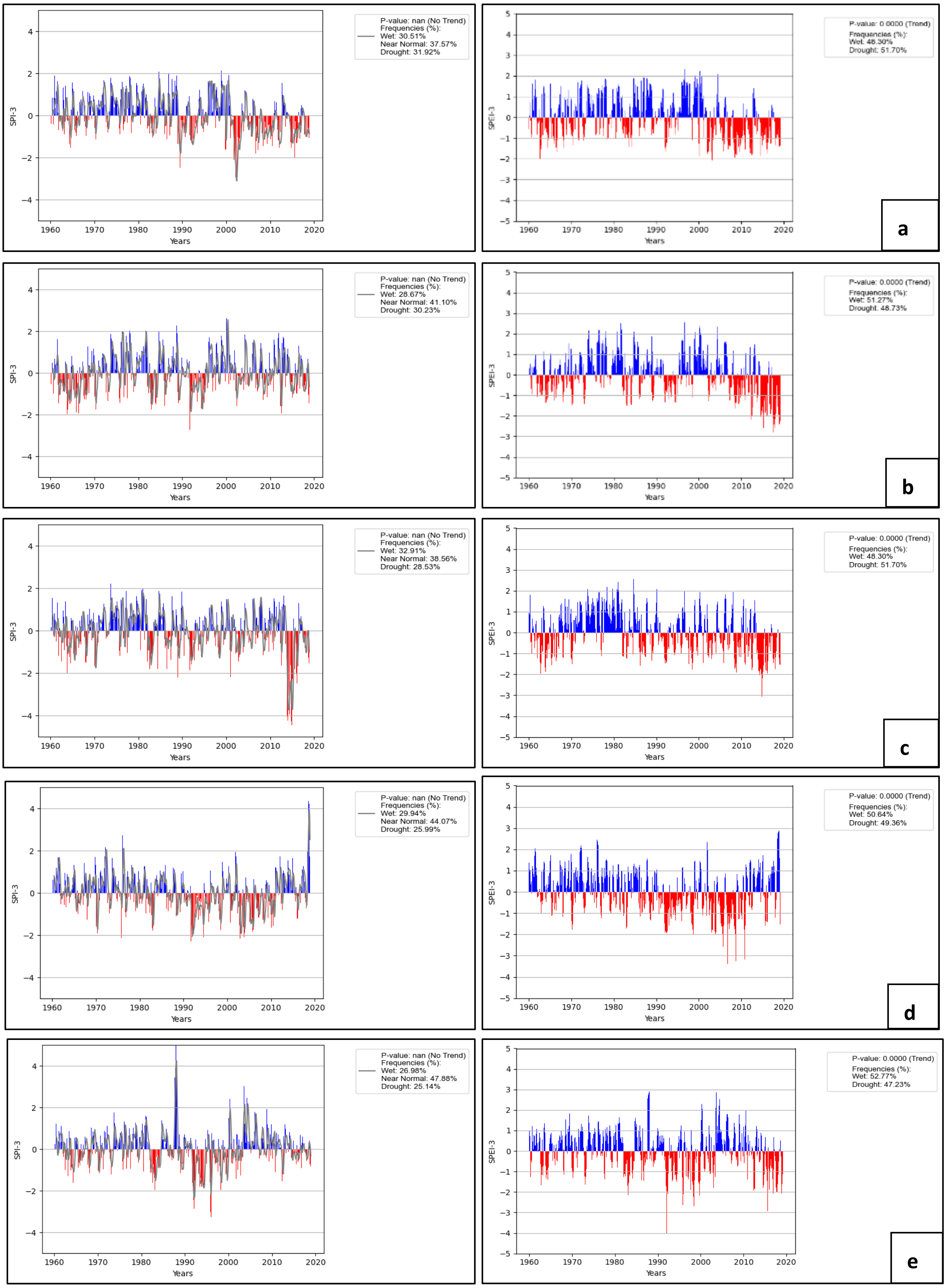


Figure 5.2: SPI and SPEI for 3-Months (a) Tzaneen (b) Sekgosese (c) Phalaborwa (d) Hoedspruit and (e) Giyani weather stations in the Mopani district

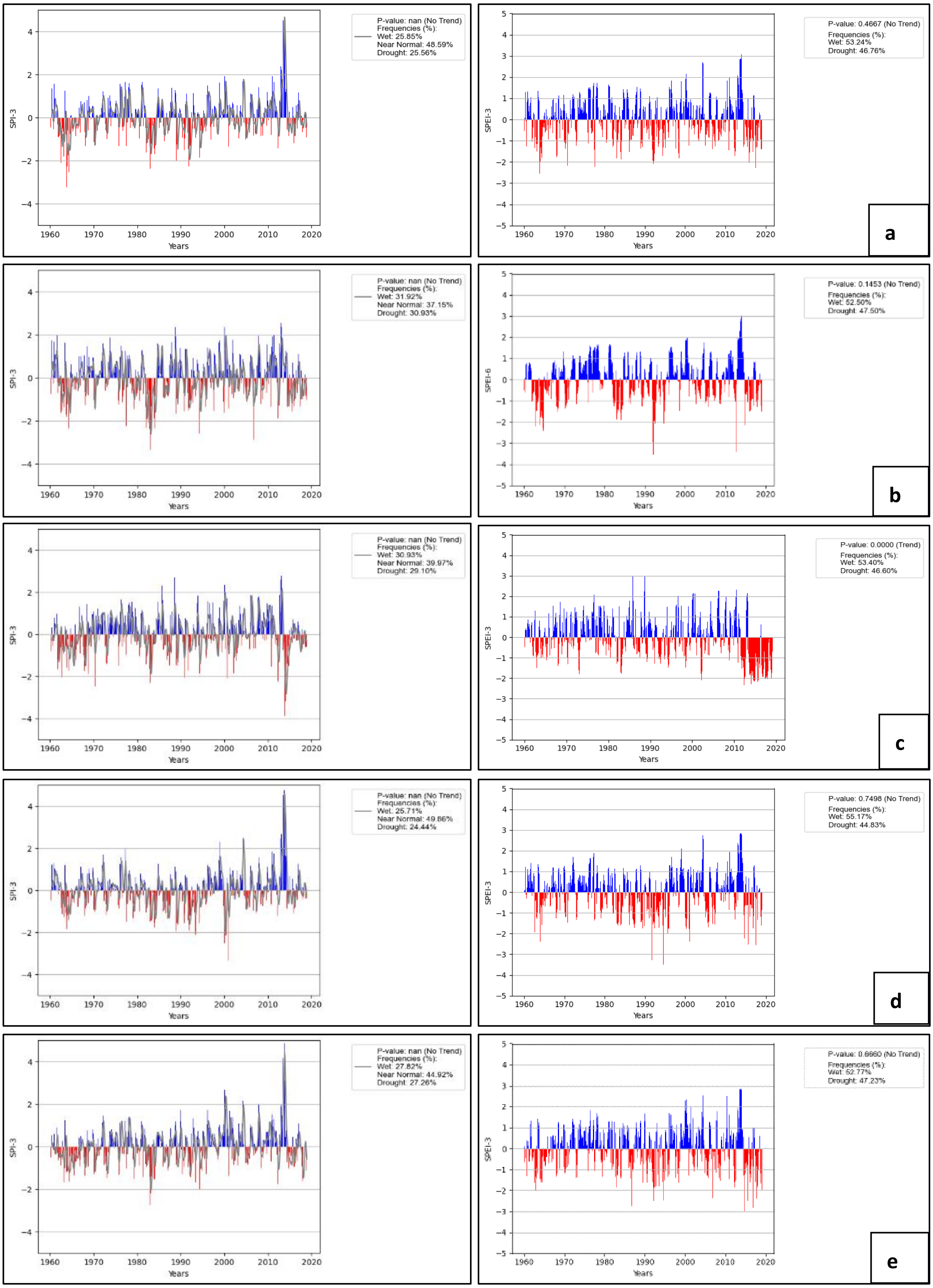


Figure 5.3: SPI and SPEI for 3-Months (a) Levubu (b) Lwamondo (c) Musina (d) Thohoyandou and (e) Tshiombo weather stations in the Vhembe district

5.3.2 Occurrence of medium-term drought conditions (6-month and/or 9-month)

This medium-term timescale gives an indication of drought conditions that may occur before planting up to the harvesting stage. The frequency of drought was higher on SPI and lower on SPEI (Figure 5.4), it implies that due to the inclusion of PET when calculating SPEI, there rainfall deficiency did not result in drought due to sufficient soil moisture. The average difference between SPI and SPEI for the Mopani district is 20% (Figure 5.4). The drought percentage for Mopani district ranges between 45-52% over the period of 1962-2018. The results are similar to the 9-month analysis (Figure 5.5).

The frequency analysis of drought given by the SPEI revealed that for the vegetative stage, a high risk of frequent droughts was observed following planting in October-November. Furthermore, results for stage 3 (flowering to grain-filling) showed that severe-extreme droughts were mostly observed at Tzaneen, Hoedspruit, and Segosese relative to planting in December, while this planting period gave lower risks for Phalaborwa and Giyani stations (Figure 5.5).

This medium-term timescale gives an indication of drought conditions that may occur before planting up to the harvesting stage. The frequency of drought was higher on SPI and lower on SPEI (Figure 5.6), which implies that due to the inclusion of PET when calculating SPEI, there rainfall deficiency did not result in drought due to sufficient soil moisture. The average difference between SPI and SPEI for the Vhembe district is 18% (Figure 5.6). The drought percentage for Mopani district ranges between 45-52% over the period of 1962-2018. The average for a 9-month analysis is 19% (Figure 5.7). The results for 6-month and 9-month are not significantly different.

The frequency analysis of drought given by the SPEI revealed that for the vegetative stage, a high risk of frequent droughts was observed following planting in October-November. Furthermore, results for stage 3 (flowering to grain-filling) showed that severe-extreme droughts were mostly observed at Levubu, Lwamondo, Thohoyandou, and Tshiombo relative to planting in December, while this planting period gave lower risks for Musina station (Figure 5.7).

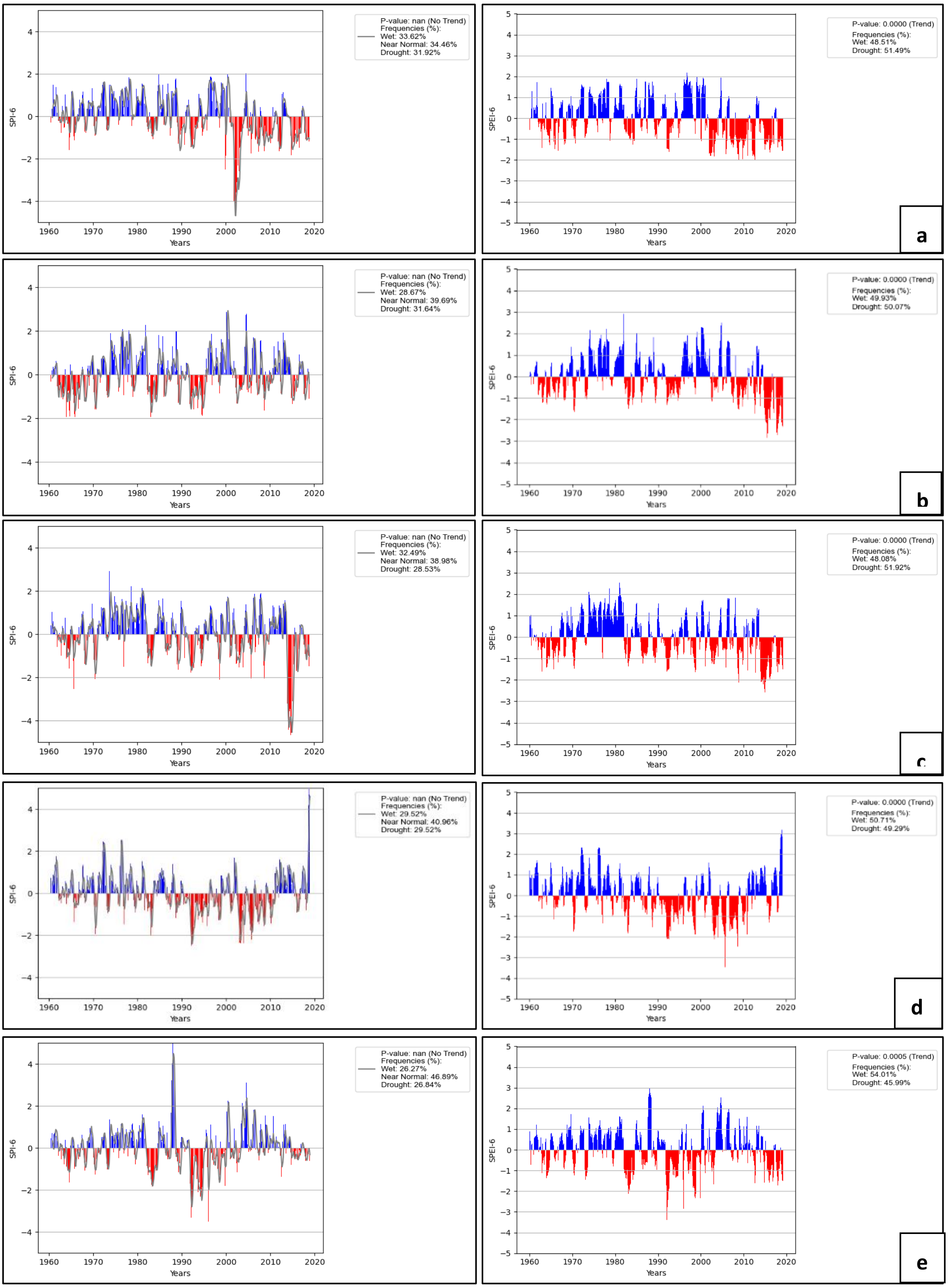


Figure 5.4: SPI and SPEI for 6-Months (a) Tzaneen (b) Sekgosese (c) Phalaborwa (d) Hoedspruit and (e) Giyani weather stations in the Mopani district

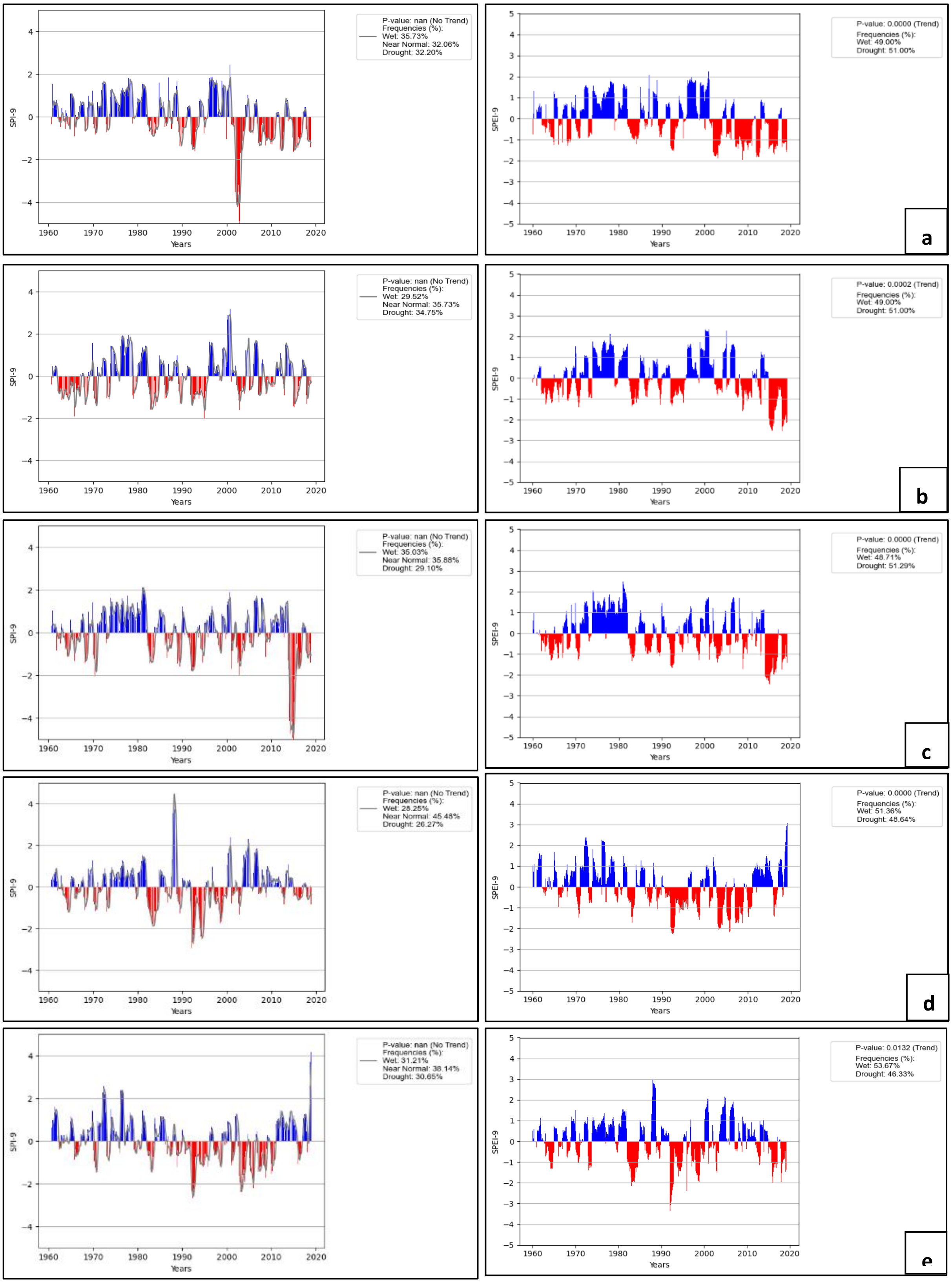


Figure 5.5: SPI and SPEI for 9-Months (a) Tzaneen (b) Sekgosese (c) Phalaborwa (d) Hoedspruit and (e) Giyani weather stations in the Mopani district

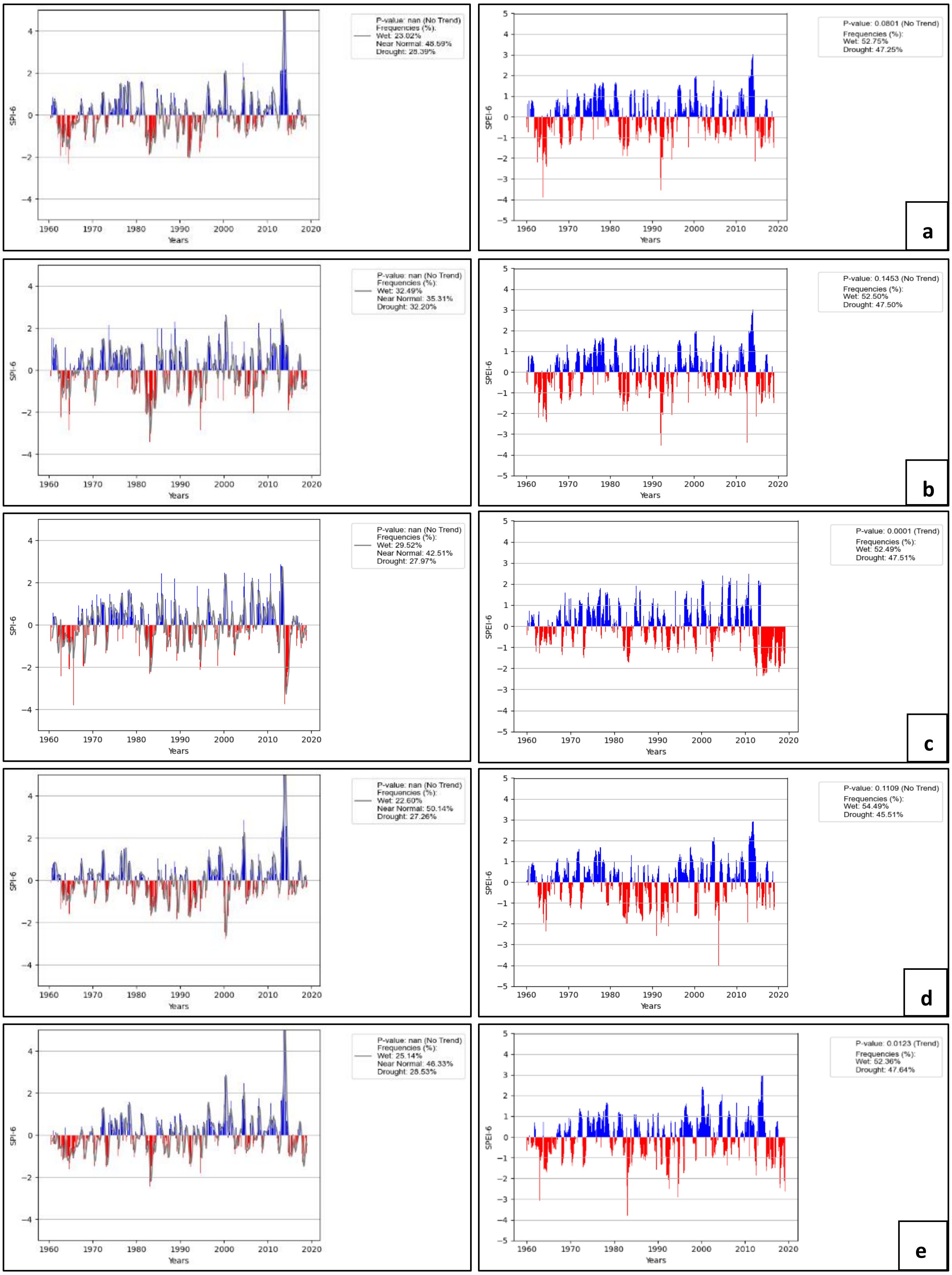


Figure 5.6: SPI and SPEI for 6-Months (a) Levubu (b) Lwamondo (c) Musina (d) Thohoyandou and (e) Tshiombo weather stations in the Vhembe district

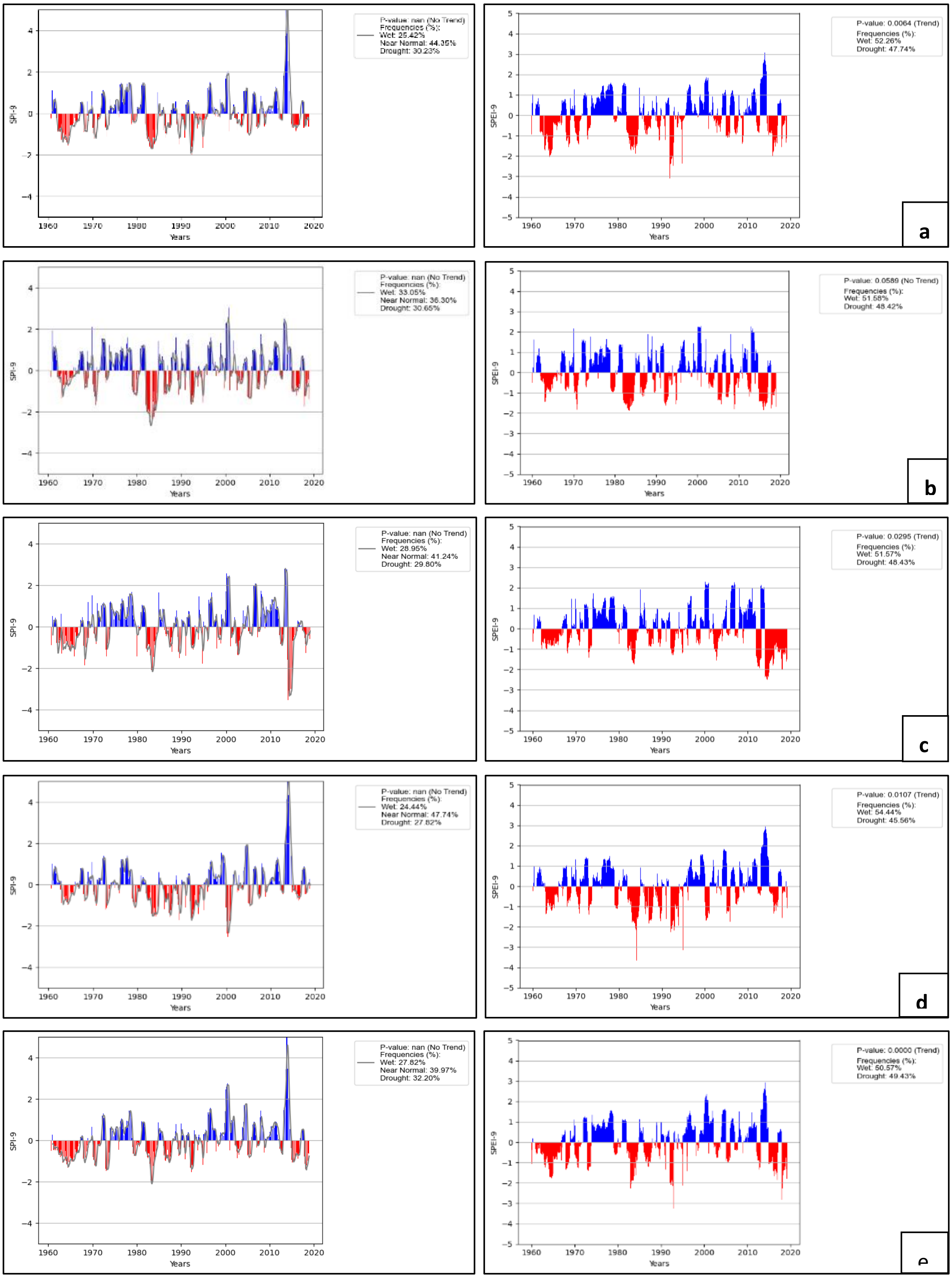


Figure 5.7: SPI and SPEI for 9-Months (a) Levubu (b) Lwamondo (c) Musina (d) Thohoyandou and (e) Tshiombo weather stations in the Vhembe district

5.3.3 Occurrence of long-term drought conditions (12-month)

This long-term timescale gives an indication of drought conditions in the Mopani that may occur for the whole year. The frequency of drought was higher on SPI and lower on SPEI (Figure 5.8), it implies that due to the inclusion of PET when calculating SPEI, there rainfall deficiency did not result in drought due to sufficient soil moisture. The average difference between SPI and SPEI for the Mopani district is 20% (Figure 5.8). The drought percentage for Mopani district ranges between 48-56% over the period of 1962-2018.

This long-term timescale gives an indication of drought conditions in the Vhembe district that may occur for the whole year. The frequency of drought was higher on SPI and lower on SPEI (Figure 5.9), it implies that due to the inclusion of PET when calculating SPEI, there rainfall deficiency did not result in drought due to sufficient soil moisture. The average difference between SPI and SPEI for the Vhembe district is 19% (Figure 5.9). The drought percentage for Vhembe district ranges between 46-49% over the period of 1962-2018.

As per SPEI results, notable seasons subjected to extreme widespread drought were identified as 1962/63, 1963/64, 1964/65, 1970/71, 1983/84, 1986/87, 1988/89, 1991/92, 1993/94, 1994/95, 2001/02, 2002/03, 2004/05, 2006/07, 2009/10, 2014/15, and 2015/16. The severe drought was observed in 1962 to 1965, 1982/83, 1991/92, and 2015/16.

Drought recurrence from 1962 to 1965 led to the number of commissions set up to look at issues of drought. There were several surveys conducted on drought conditions in different parts of the country around 1960, as well as appointments of extension and research services to assist farmers in feeding their animals effectively during droughts, the Department of Agriculture's Technical Services in 1961, and the Marais Commission of Enquiry into Agriculture that was established in 1966 (Vogel *et al*., 2000). These commissions confirmed some problems in the farms and made provisions for the legislation on the Subdivision on Agricultural Land Act (Act No. 70 of 1970).

The seasonal average rainfall in the Mopani and Vhembe districts experienced the wettest season in 1999/2000. A wide range of heavy rainfall was experienced in the Mopani and Vhembe districts in February 2000, due to tropical cyclone Eline that invaded Southern Africa in February 2000 (Dyson & van Heerden, 2001). Other particularly wet seasons are 1975/1976, 1976/1977, 1987/1988, 1995/1996, 1999/2000, 2005/2006 and 2011/2012. 1987/88, 1999/00, 2003/04, 2012/13 and 2013/14

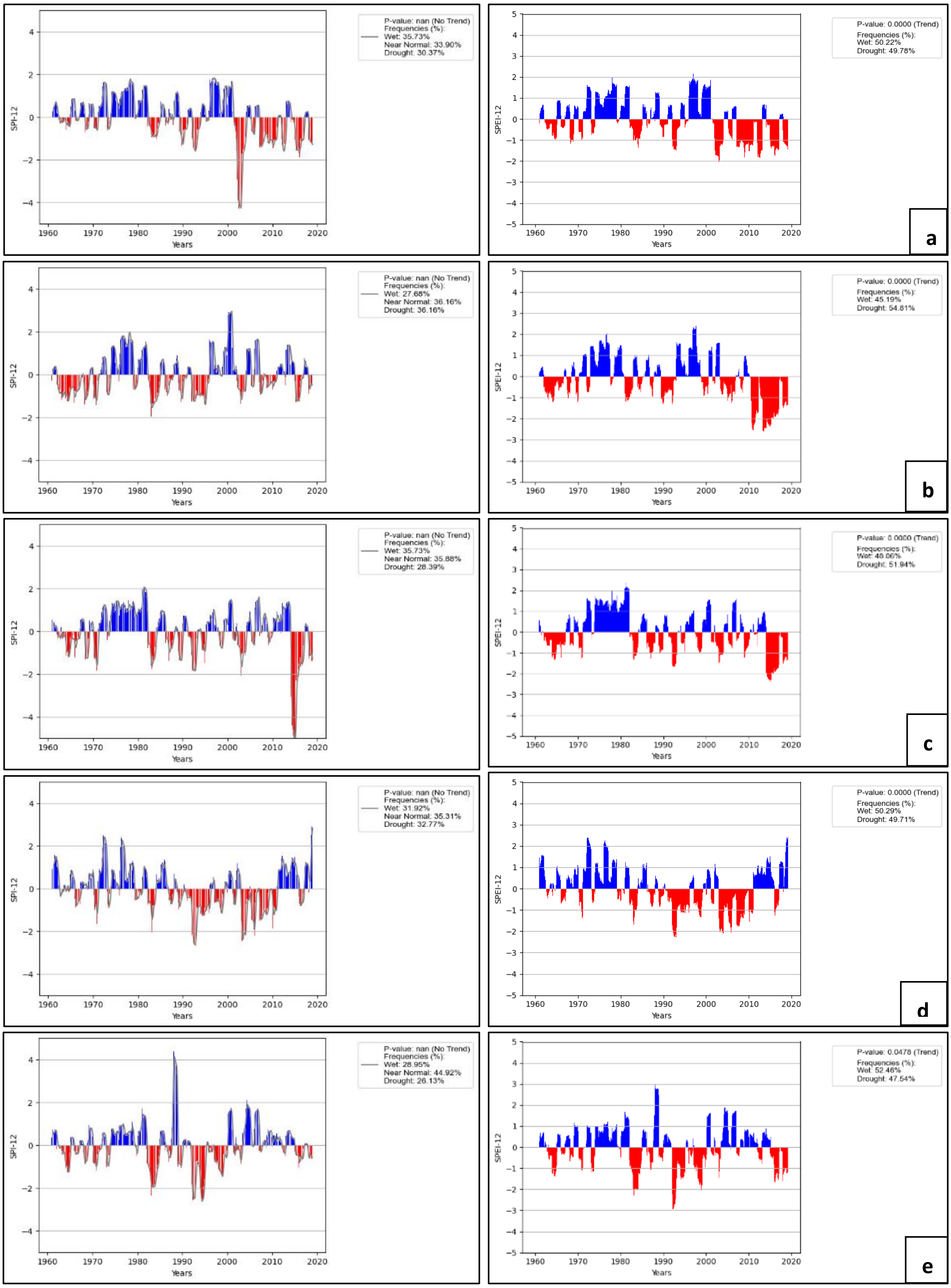


Figure 5.8: SPI and SPEI for 12-Months (a) Tzaneen (b) Sekgosese (c) Phalaborwa (d) Hoedspruit and (e) Giyani weather stations in the Mopani district

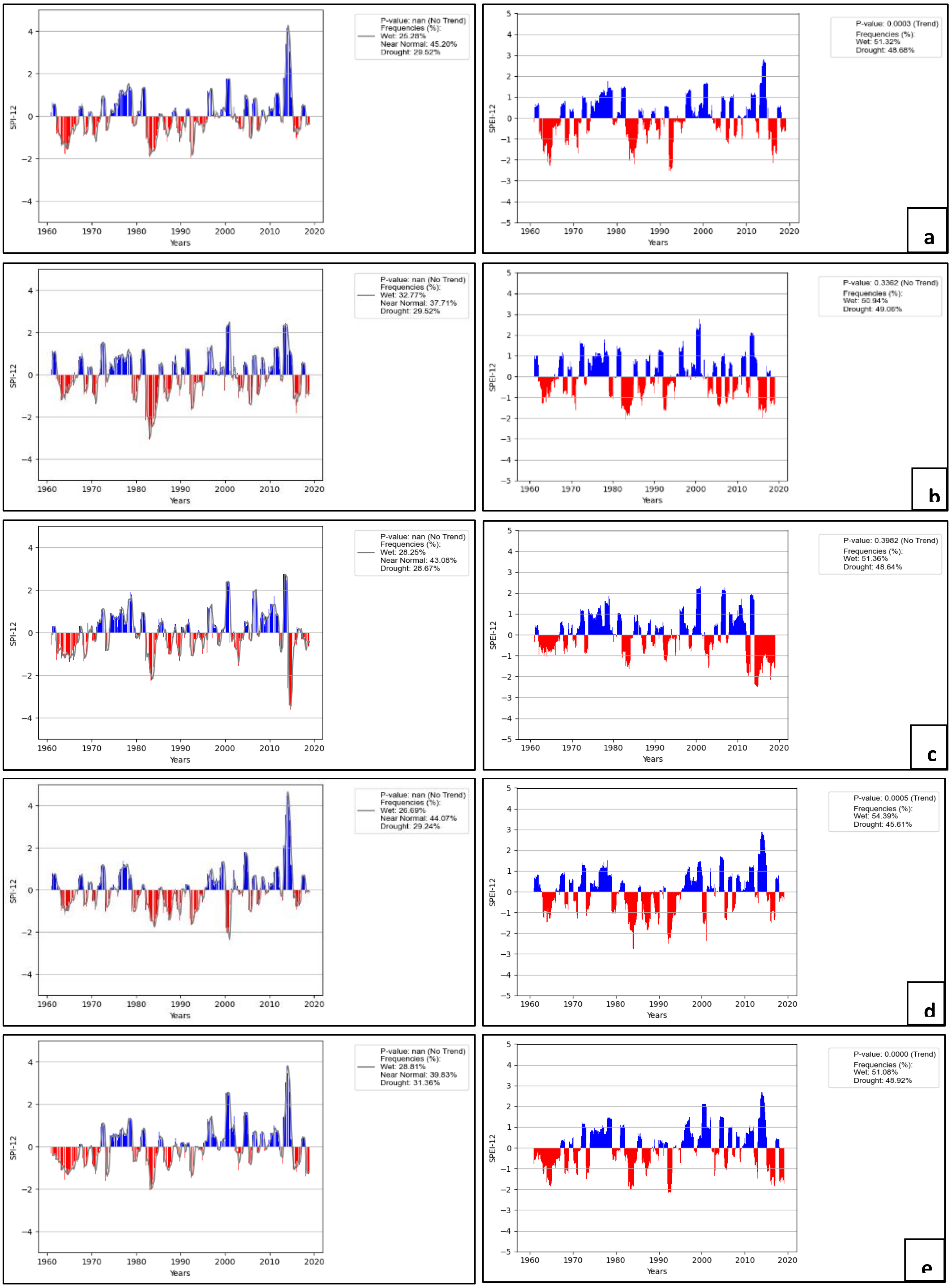


Figure 5.9: SPI and SPEI for 12-Months (a) Levubu (b) Lwamondo (c) Musina (d) Thohoyandou and (e) Tshiombo weather stations in the Vhembe district

5.4 Summary of findings and recommendations

Analysis of water balance during the widespread droughts given by SPEI showed that the occurrence and the severity of drought were aggravated by the low rainfall amounts together with high evapotranspiration rates throughout the rainfall season. As per SPEI results, notable seasons subjected to extreme widespread drought were identified as 1962/63, 1963/64, 1964/65, 1970/71, 1983/84, 1986/87, 1988/89, 1991/92, 1993/94, 1994/95, 2001/02, 2002/03, 2004/05, 2006/07, 2009/10, 2014/15, and 2015/16. The severe drought was observed in 1962 to 1965, 1982/83, 1991/92, and 2015/16. SPEI results further revealed 1987/88, 1999/00, 2003/04, 2012/13 and 2013/14 as being the extreme wet seasons in the area for the analysis period.

Future climates analysis by both SPEI projected increased frequency of droughts that would often lead to poor crop performance and failure, by the near-future to the end of the intermediate-future period. These conditions are then expected to return to normal at the beginning of the far-future climate period with a slight intensification of drought detected towards the end of the analysis period.

This study revealed that by computing the likelihood of droughts occurring after effective planting dates, agricultural decisions can be strengthened and more effectively supported. The timing of the drought also demonstrated the need to evaluate it in relation to the various phases of the crops because, while farmers would want an equal distribution of rainfall throughout the season, in fact, this is not ideal. Therefore, to reduce the potential effects of drought under climate change, sustainable water management strategies like conservation agriculture should be planned. Moreover, planning and decision-making before and during droughts can be aided by crucial communication between scientists, decision-makers, and farmers.

If the world is to ever achieve the 2030 Global Agenda on Sustainable Development goals of achieving zero hunger, providing clean water and sanitation, creating jobs and economic growth, improving livelihoods, and ending poverty, water management and agriculture must flourish (Raidimi & Kabiti, 2017; Zwane & Montmasson-Clair, 2016). Policy and decision-makers should adopt radical measures to transform food production systems and the entire agriculture value chain in order to achieve these goals sustainably. These measures should include cutting-edge technologies, processes, and systems that address agricultural water management while also ensuring water, energy, and food security (Antle *et al*., 2017; Capalbo *et al*., 2017).

The WEF Nexus is one of these systems approaches. It accounts for synergies and trade-offs within WEF sectors because they are inherently linked to one another as well as describing and simplification the intricate relationships and interactions among natural resources (Shikwambana *et al*., 2021; Nhamo *et al*., 2019b). It is an integrated strategy to resource development, utilisation, and management since the WEF Nexus assures that changes in one sector do not have an impact on the other two (Nhamo *et al*., 2019b). Through the use of cutting-edge agricultural water management technologies, an integrated approach to resource management ensures that the food needs of a growing population are met in the event that water supplies become exhausted. Planning scenarios and developing specialised adaption techniques at the local level, or even at the household level, that would produce resilient communities in the face of climate unpredictability and change are all part of managing these resources for sustainability.

The WEF Nexus is an essential systems approach that can ensure sustainability and provide policy and decision-making with evidence on priority areas needing intervention because climate change is multidimensional and affects all sectors, including, among others, water, food, energy, health, infrastructure, ecosystems, and biodiversity (Shikwambana *et al*., 2021; Nhamo *et al*., 2019b). The WEF Nexus can thus supplement existing tools and observed data in creating resilient communities for sustainable development given the significance and urgent need to undertake climate change adaptation measures at the local level and adjust to the new norm.

5.5 Conclusions

The study used observed data to assess climate variability and change from 1960 to 2018 in Vhembe and Mopani districts of Limpopo Province in South Africa. The primary goal of this study was to evaluate past and potential drought events in connection to smallholder farmers' coping and adaptation techniques in the South African districts of Vhembe and Mopani. The SPI, and SPEI were used in the study to identify the beginning, severity, and temporal fluctuations of drought. There were differences in the two indices' abilities to detect droughts. The SPEI was used to consider evapotranspiration while calculating the potential consequences of drought for each stage of the crop.

In addition to helping understand how seasonality changes over time, the information that was gathered was also crucial in terms of giving support for resilience-building and adjusting to the altered crop growing season. This new understanding of the changing seasons was enhanced by the inclusion of observed data, which revealed instances of intra-seasonal droughts or significant rainfall over brief intervals during the rainy season, as shown by the SPI and SPEI study. In order to recognise the hazards that typically go along with such changes, it is essential to detect observed changes in climatic regimes. The hazards posed by the identified climatic changes were then utilised to suggest context-based adaptation measures especially for the district. Context-based adaptation techniques are essential since the effects and severity of climate change differ from place to place. As a result, smallholder farmers' adaptation should be planned in accordance with the climate change that is occurring in each specific location.

CHAPTER SIX

ENHANCING THE RESILIENCE AND ADAPTIVE CAPACITY OF SMALLHOLDER FARMERS TO DROUGHT IN THE LIMPOPO PROVINCE, SOUTH AFRICA.

The following paper has been published as part of this chapter:

Shikwambana, S.; Malaza, N. Enhancing the Resilience and Adaptive Capacity of Smallholder Farmers to Drought in the Limpopo Province, South Africa. *Conservation* 2022, *2*, 435-449. https://doi.org/10.3390/conservation2030029.

Abstract

Climate change has caused substantial losses, especially to smallholder farmers whose main source of livelihood is derived from agriculture. Climate change impacts can be reduced by enhancing coping and adaptation strategies. This study explores the coping and adaptation strategies of smallholder farming communities in the Limpopo Province, South Africa. As part of the assessment and analysis of drought, multiple sources of data were consulted, including 200 households' socio-economic information, focus group discussions, and interviews. Extreme drought events are increasing, impacting negatively on smallholder farmers' livelihoods. Adaptations to changing weather patterns were observed in smallholder farmers through planting early maturing plants and drought-tolerant crops, altering planting dates, crop diversification, and irrigating in addition to non-farming activities. There is a need to enhance these context-based adaptation strategies to reduce risks and vulnerability and increase household resilience. Several socioeconomic developments and significant ecological deterioration appear to limit opportunities for long-term adaptation to drought.

Keywords: resilience; coping; adaptation; smallholder farmers; sustainability; climate change.

6.1 Introduction

There has been an adverse impact of climate change on the physical and biological systems of most continents all over the world for the past few decades (Porter *et al*., 2014). Global agricultural production has declined by 1–5% per decade due to climate change, according to Porter *et al*. (2014). Global agriculture will also be adversely affected by these changes, especially in tropical and subtropical regions (Porter *et al*., 2014). In countries where agriculture dominates the economy, such as sub-Saharan Africa, climate change has a disproportionate impact on agriculture. Agricultural systems, especially food production, are already vulnerable to rapid and uncertain changes in temperature and rainfall patterns in the subcontinent (Ncube *et al*., 2016). Climate change in tropical regions is predicted to exacerbate this trend in the coming decades, resulting in a significant decline in the production of important and staple food crops (Ncube *et al*., 2016; Porter *et al*., 2014).

As a result of a lack of knowledge and technology, rural communities in South Africa remain susceptible to natural disasters and climatic hazards (Ncube *et al*., 2016;). Climate change has been connected to various natural disasters occurring in South Africa and causes widespread food and water insecurities (Shikwambana *et al*., 2021). South Africa is particularly vulnerable to climate change, because of its high dependence on climate-sensitive economic sectors and agriculture (Porter *et al*., 2014). Smallholder farmers and rural-based communal farmers are highly vulnerable to climate change as they lack the resources to adapt (Shikwambana *et al*., 2021). Regardless of insufficient governmental support, a viable option is to use indigenous knowledge systems to mitigate the effects of drought on agricultural production in developing economies (Masipa, 2017). Frequent droughts will influence both rural economies and food security, as they will reduce agricultural outputs, which directly impacts rural communities (Muyombo *et al*., 2017).

South Africa's climate-related disasters are analyzed besides/in addition to/other than the food and water security challenges. However, identifying vulnerable households is critical to developing effective adaptation and mitigation strategies. These interlinkages between climate change, water, and food insecurity bring to the fore the need to adopt transformative and integrated approaches to address contemporary challenges that crosscut all sectors. Several studies that focus on South Africa have analyzed household vulnerability but have neglected to examine the dimensions of household vulnerability (Shen *et al*., 2022; Ahmadi *et al*., 2021; Alhassan *et al*., 2019). Consequently, due to climate change, the emergency response starts at the local level, which means determining who is likely to be affected and which households should be considered (Alhassan *et al*., 2019).

Increasing food security requires understanding and addressing socio-ecological thematic areas, such as drivers of change, risk, climate, food security, water security, food sustainability, and nexus planning (Shikwambana *et al.,* 2021; Masipa, 2017). In addition to ensuring human and environmental health, the above thematic areas demonstrate sustainable food systems and efficient water use in agriculture. Irrigation management has similarly become increasingly dependent upon remote sensing, particularly in irrigation scheduling. As precision agriculture advances, it is possible to determine the moisture content of crops in cultivated fields and determine crop water requirements, and estimate water required for crop growth using freely available remote sensing products (Masipa, 2017). Variable irrigation scheduling requires this kind of weather, rainfall, and soil moisture information. Exhausting social media and mobile applications can provide useful information to the farmers for better management and productivity, besides/in addition to market information.

Coping strategies are actions taken by people who have been threatened with loss of livelihood. This involves managing resources during and after a drought to mitigate the effects of drought. In the study by Eriksen *et al*. (2008), coping mechanisms were defined as actions and activities that happen within existing structures and systems, for example, diversification on farms. Most agricultural programs are initiated at national levels of government for provincial and local implementation; however, such programs are not always adapted to local conditions (i.e., on the specific farm). Climate change will have local repercussions for all agricultural plans and programs, so they must focus on local conditions.

Water management has become more and more dependent on technology, specifically hydrological and water management models. The technological advances in agriculture applied through research on smallholder agriculture guide policy and decision-making on formulating coherent and strategic policies towards resilience and attainment of Sustainable Development Goals (SDGs). According to Maka *et al*. (2019), smallholder farmers in South Africa have adopted several strategies, such as introducing diverse crop varieties, introducing new crop cultivars, changing the time of farmer operations, crop rotation, promoting crop diversification, promoting climate change awareness, using different planting dates, and educating farmers about climate change.

This study explored the resilience and adaptive capacity of smallholder farmers to drought in the Vhembe and Mopani districts of the Limpopo Province. Smallholder farmers' livelihood in the two districts relies on rainfed agriculture which is vulnerable to drought as rainfall patterns changes (Shikwambana *et al*., 2021). Therefore, there is a need to enhance the resilience of smallholder farmers through innovative technological interventions. This is necessitated by the high vulnerability and risk of smallholder farmers to worsening climate change conditions as they generally lack the resources to adapt. This study, therefore, intends to inform policy and decision-makers on informed strategies that enhance the resilience of rural livelihoods. There is no clear understanding of how farmers can be helped and empowered to cope and adapt to droughts in the long run. Therefore, this study proposes a framework for developing adaptation strategies for smallholder farmers to improve their livelihoods. These methods can be applied to other areas since adaptation strategies developed at the local level are more effective than those developed at the global level. The results of this study add to the knowledge of coping and adaptation to drought and can be extrapolated to other areas facing similar climate change impacts.

6.2 Materials and Methods

6.2.1 Study area

The study was conducted in the Vhembe and Mopani districts from January to April 2018. Smallholder farmers from 9 centers, namely, Guwela, Mhlava Welemu, Hlaneki, Berlyn, Naphuno, Mamitwa, Tzaneen, Lambani, and Khalavha. The service centers were invited with the help of agricultural advisors. Limpopo Province consists of five (5) districts, namely: Vhembe, Mopani, Waterberg, Capricorn, and Greater Sekhukhune (Figure 6.1).

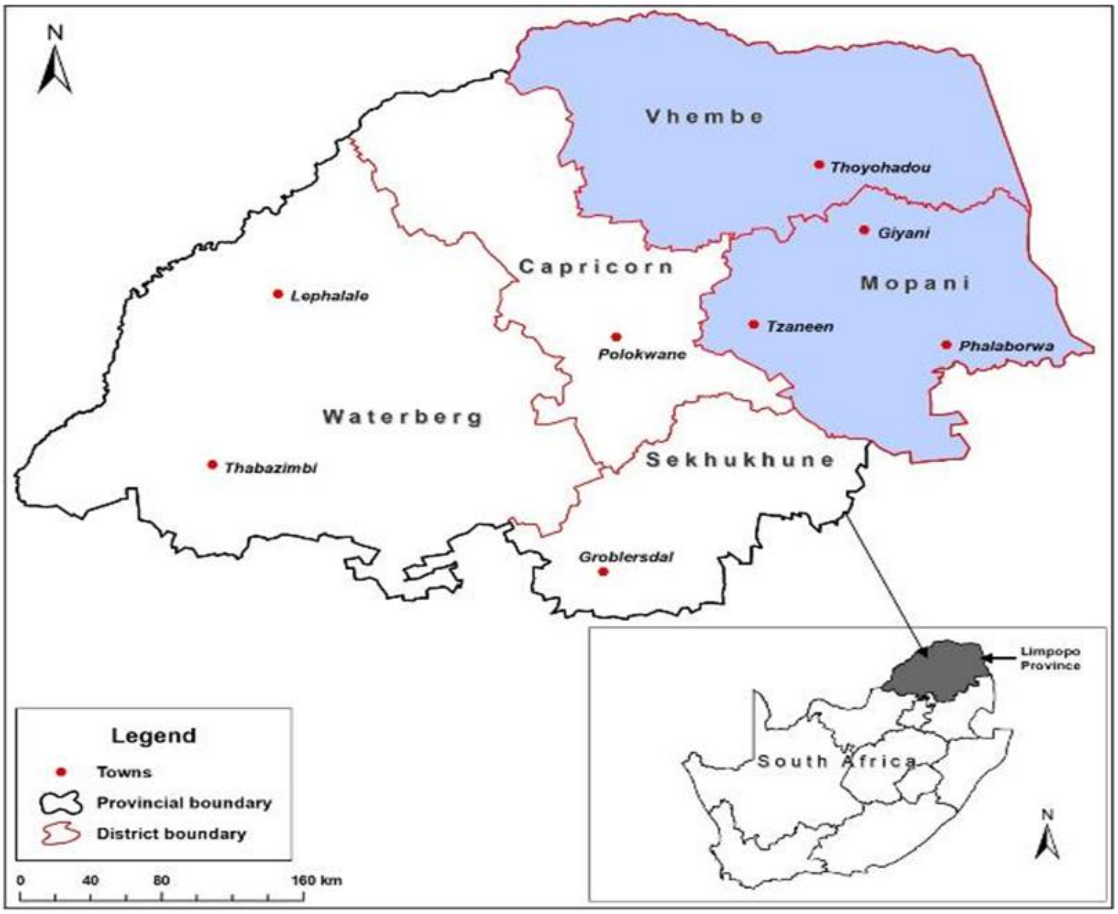


Figure 6.1: Limpopo Province map showing the location of Vhembe and Mopani districts

Limpopo Province is situated in the northern part of South Africa and occupies an area of 12.46 million hectares. The study focused on the farmers from the Vhembe and Mopani districts Municipalities since they are considered climate change hotspots in the province due to many smallholder farmers and the temperature variations that occur in the area (Shikwambana *et al*., 2021).

The Vhembe district experiences average an annual temperature ranging between 14 °C and 29 °C (DFED, 2004). Average rainfall of 300 mm to 400 mm per year falls during the summer in the district (DFED, 2004). The Vhembe district has a unique characteristic of being suitable for growing tropical and subtropical fruits in the Levubu Tropical Valley. Several irrigation schemes are spread along the rivers of the Nwanedi Valley, which is known for its tomato production (DFED, 2004). Therefore, many investments have been made in fruit and vegetable production and value-added infrastructure.

The average maximum temperature in the Mopani for January ranges from 21 °C to 37 °C; the average minimum temperature is between 5 °C and 12 °C; the average annual temperature is between 13 °C and 27 °C (DFED, 2004). Average annual rainfall of approximately 400–500 mm falls on the eastward side of the Drakensberg escarpment, while 600–800 mm and 800–1000 mm fall on the foot and along the escarpment, respectively (DFED, 2004). Rainfall in the Mopani District is generally low, particularly in the lower parts of the Giyani and Ba-Phalaborwa municipalities. Letaba River catchment and all its tributaries are the main source of surface water for Mopani. Borehole water has the potential to supplement surface water. There are rivers throughout the district, some of which are used for irrigation. Among the agricultural products are citrus, mangoes, vegetables, poultry, and livestock. Tzaneen, Letaba, and Maruleng municipalities are also heavily dependent on agriculture as one of their key economic sectors. There is generally a shortage of water in Giyani, so irrigation is limited in this area. According to the Limpopo state of the environmental report (DFED, 2004), the district has a wide range of soil capabilities for crop and livestock production.

6.2.2 Data Sources

To explore participants' strategies for livelihoods, the questionnaire was based on the Sustainable Livelihoods Framework's assets. To achieve the research objectives and answer the research questions, the study collected both primary and secondary data. A variety of primary data sources were utilized to collect various aspects of drought and drought coping and adaptation strategies, including socio-economic interviews with 200 households, focus groups, and informal interviews with smallholders. Secondary data were sought from a variety of sources, including records, authentic materials, published and unpublished articles, websites, and books. In the study, only smallholder farmers engaged in dryland or mixed farming systems were considered.

6.2.3 Data Analysis

A statistical package for social sciences (SPSS) software program was used to enter, code, and analyze the information from the questionnaires. There were several analyses conducted, including the generation of descriptive statistics and forms of statistical analysis, such as comparison of mean and proportion. Through conducting thematic tree diagrams and engaging in a comparison of the themes found in interview transcripts and voice recorders, qualitative data were analyzed. A theme, a trend, and opinions that emerged frequently were analyzed. Participants' experiences, perceptions, and expressions were also considered in the analysis. Multiple data sources were used to collect information about drought conditions, impacts, events, drought adaptations, and coping strategies, including socio-economic interviews, focus group discussions, observation, and informal interviews with smallholders.

6.2.4 Conceptual Framework: Probit Model

The statistical data analysis, the StataCorp. 2021. Stata Statistical Software: Release 17. StataCorp LLC: College Station, TX, USA [12], was utilized to assess how smallholder farmers adapt to drought and factors that influence implementation strategies. To understand the factors that determine the capacity building of smallholder farmers, the study employed a binary probit model. The probit model is a statistical probability model with two categories in the dependent variable (one and zero). Probit analysis is based on the cumulative normal probability distribution. The probit model can be presented as follows:

$$Y = \Pr(Y = 1|X) = \Phi(X^T\beta) \quad \textbf{Equation 6.1}$$

where Pr is the probability and Φ denotes the cumulative Distribution Function (CDF) of the standard normal distribution. The X^T is the vector of coefficients to be estimated and β represents the parameters to be estimated using the maximum likelihood method.

The binary dependent variable, Y, takes on the values of zero and one. The outcomes of y are mutually exclusive and exhaustive. The dependent variable, Y, depends on X^T observable variables. Although the values of zero and one were observed for the dependent variable in the probit model, there was a latent, unobserved continuous variable, y*. Hence it can be shown that probit model is similar to the latent variable model which can be presented as follows:

$$y^* = X^T\beta + \mathcal{E}, \text{ where } \mathcal{E} \sim N(0,1) \quad \textbf{Equation 6.2}$$

The dummy variable, Y, was observed and was determined by y* as follows:

$$Y = \{1 \; if \; y^* > 0; \; 0 \; otherwise\} = \{1 \; X^T\beta + \mathcal{E} > 0; \; 0 \; otherwise\} \quad \textbf{Equation 6.3}$$

The point of interest relates to the probability that y equals one given the values of X. The two models in Equation (3) are equivalent by symmetry of normal distribution, and it can be shown as follows:

$$Y = \Pr(Y = 1|X) = \Pr(y^* > 0)$$

$$= \Pr(X^T\beta + \mathcal{E} > 0) \quad \textbf{Equation 6.4}$$

$$= \Pr(\mathcal{E} > -X^T\beta)$$

$$= \Phi\ (X^T\beta)$$

where Φ was the cumulative distribution function of ε. The probit model assumed that the data were generated from a random sample of size N with a sample observation denoted by i, where i = 1, …, N. Thus, the observations of y must be statistically independent of each other to rule out serial correlation. Additionally, it was assumed that the independent variables (the responses to the consumer survey questions) were random variables.

In order to estimate the above model in (X), the maximum likelihood method is used. The relationship between a specific variable and the outcome of the probability is interpreted by means of the marginal effect which accounts for the partial change in the explanatory variable X^T on the probability Pr (Y = 1|X), holding other variables constant.

6.3 Results and discussion

6.3.1 Impacts of socio-economic status on coping and adaptation

Around 71 percent of the farmers were over 56 years old, and only 6 percent were in the 18-35 age group (Figure 6.2a). Youth and middle age tend to cope and adapt to drought compared to the old people. However, the low participation in farming by youth is a major challenge and impacts the coping and adaptation to drought. Technology development in the agriculture and water sectors is important for resource management, besides sustainability and food security, hence young people cope and adapt to drought fast compared to old people. An alternative reason for slow adaptation is that older farmers tend to rely on their indigenous knowledge to manage their farms since they are less likely to adopt new sustainable practices (Ndiritu *et al*., 2014). They are losing the reliability of their indigenous knowledge due to frequent drought occurrences and rainfall and temperature variability.

A key to maximizing smallholder farmers’ productivity is integrating indigenous knowledge with scientific agriculture management practices. If agriculture is to fulfill the mandate of being the main driver within the Vhembe and Mopani districts in the future, there is a need to establish younger farmers since the aging population structure of smallholder farmers seems to suggest that the numbers will decline in the future.

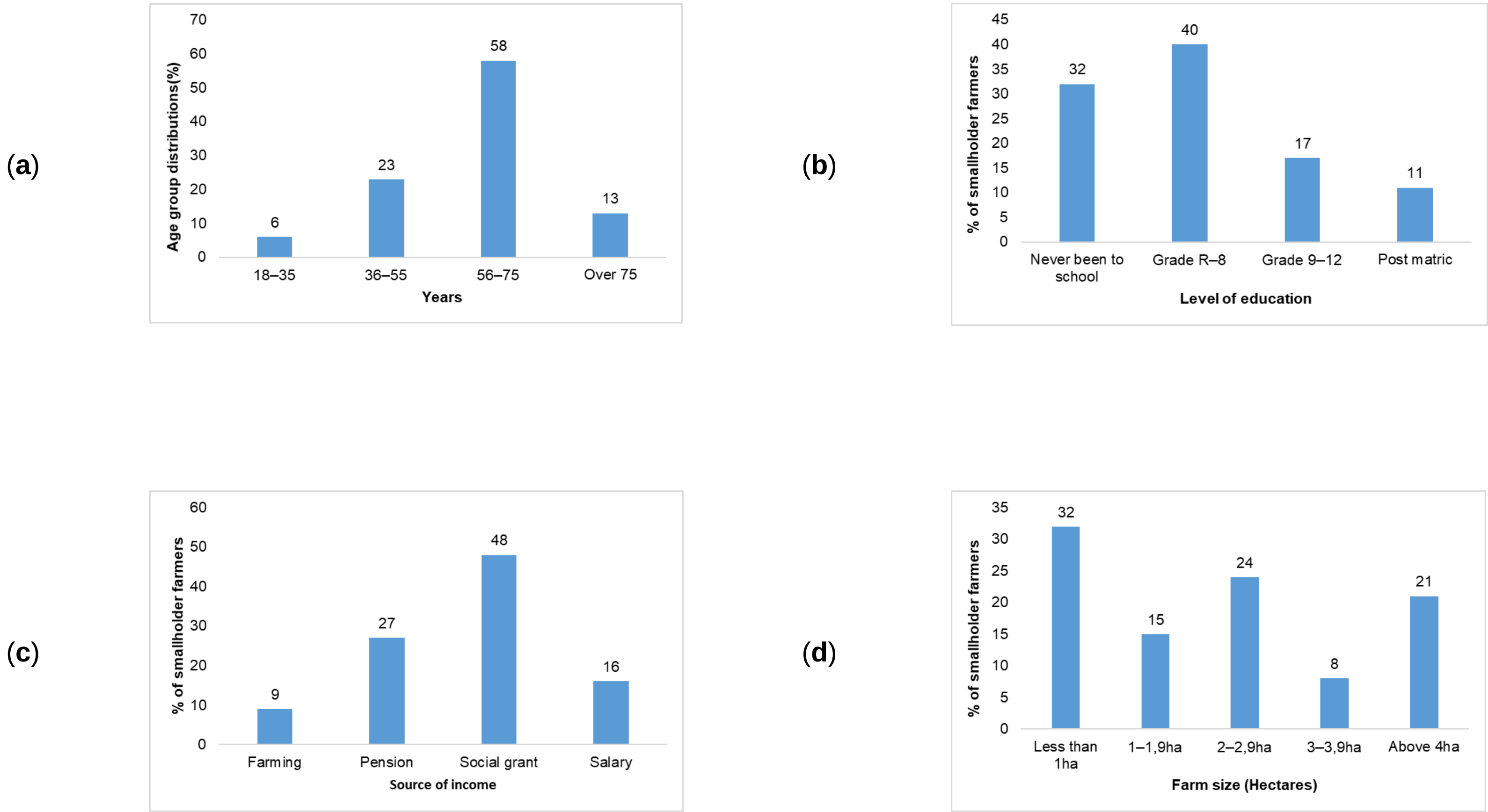


Figure 6.2: Smallholder farmers (a) age group, (b) education level, (c) source of income, and (d) land size in study area (*n* = 200)

Based on the responses to the education questionnaire, four groups were developed, corresponding to the level of education of the farmers, ranging from no formal education to post-matriculation. A survey found that 17 percent of farmers had been to school beyond high school, 40 percent had reached primary school, 32 percent had no formal education, and 11 percent had attended post matric school (Figure 6.2b). Based on these findings, we can agree with other studies that most smallholder farmers have limited education (Lehohla, 2011; Mudhara, 2010).

Low literacy levels have an indirect impact on the coping and adaptation strategies since technology and information have both advanced, requiring a certain level of formal education and training. Investing in education can similarly improve literacy rates, which are a major barrier to many desirable outcomes for coping and adaptation strategies to resist drought impact. These rates are a key part of addressing recurring drought vulnerability in the study area. In most cases, climatic information is presented in scientific language, making it difficult for farmers who are illiterate to understand it. Drought is easier to cope with and adapt to for smallholder farmers with higher levels of formal education and training. Farmers' ability to carry out some farming activities may be affected by the level of education possessed or attained, and this may be linked to poverty in the study area.

About 48% of smallholder farmers in the Vhembe and Mopani districts build their livelihoods using social grant payments from the government (Figure 6.2c). It is important to note that even though smallholder farmers received grants as their main income source, they continued to participate in farming activities, mostly to be less reliant on buying food from the market. Usually, these grants protect the rural poor from unemployment and isolate them from employment opportunities. Furthermore, these transfers are intended to reduce socio-economic distress; yet they also perpetuate a reliance on resources outside of the labor market. From a welfare perspective, food security, asset ownership, and credit access were the most vulnerable for smallholder farmers dependent on social grants, and they had the most difficulty coping with and adapting to droughts.

According to the size of a farmer's land holdings, responses were divided into five categories: less than 1 hectare; 1 to 1.9 hectares; 2 to 2.9 hectares; 3 to 3.9 hectares; and above 4 hectares. The average scale of farms per household is between 3.0 and 3.9 ha, and 47% of the farmers had farms smaller than 2 ha. About 24% of farmers had farms larger than 2 ha, followed by 21% of farmers with farms greater than 4 ha; and only 8% had farms smaller than 3.0 ha (Figure 6.2d). The results confirmed previous studies that showed most smallholder farmers in South Africa own less than 2 ha of land (Mpandeli & Maponya, 2014; Mudhara, 2010). The findings by Mudhara (2010), indicate that only 13% of South Africa's farmers are smallholders, and they tend to farm predominantly in former homeland areas, which are dominated by resource-poor black farmers. Increasing farm production could assist in generating sufficient food for these households.

In addition to asking whether the respondents were employed, they were likewise asked if they had an additional source of income. A survey of 72% of respondents revealed that they were unemployed (Figure 6.3a). To meet their daily food needs, most farmers receive social grants from the government. According to the results of the survey, casual workers mostly work on the Department of Public Works projects in the area, including the Expanded Public Works Programme (EPWP). Most commercial banks prefer to lend money to farmers with a proven income stream and those who are economically active (Baiyegunhi & Fraser, 2014). The lack of ownership rights to their land prevents most smallholder farmers in South Africa from obtaining loans to invest in their farms due to the lack of collateral (van Schalkwyk *et al*., 2011). Farmers can therefore overcome the financial constraints that prevent them from adapting to the drought when they need access to credit (Mudhara, 2010).

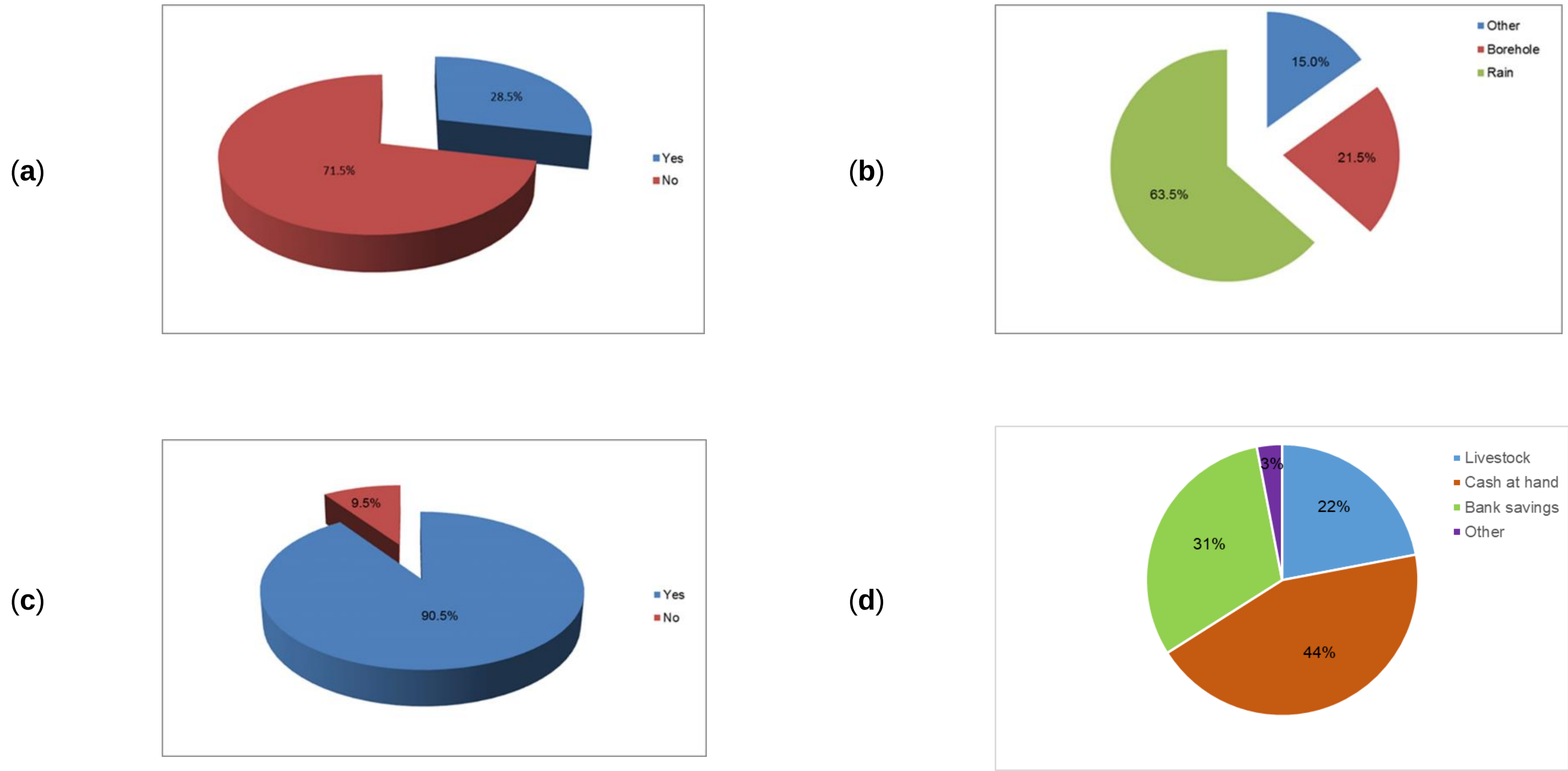


Figure 6.3: Smallholder farmers (a) water source, (b) employment status, (c) access to credits, and (d) saving money in study area (*n* = 200)

A well-developed commercial farming community owns 87% of the total area (Mudhara, 2010). As a result of apartheid, the system of commercial farming and smallholder farming in South Africa remains dualistic (Neves & Du Toit, 2013). Additionally, apartheid created inequalities within the population, resulting in constant poverty and food insecurity for most black people, even after quite 28 years of democracy. There are many uncertainties associated with the ownership of communal lands in the Limpopo Province, which makes it difficult for smallholder farmers to adapt to drought impacts. This, in turn, requires specialized equipment and financial investment to deal with drought.

Moreover, the study explored the identification of the available water resources; farmers must identify the source of their farming water. Figure 6.3b shows the water sources used by the farmers in the study area. The study shows that 64% of the farmers rely on precipitation to grow crops and raise livestock, and 22% had their own boreholes. It may be that this explains why their farming is mainly seasonal and why their output is low. The challenge of water access in the study areas, particularly Greater Giyani, is by all accounts predominant, and water shows a basic role in the coping and adaptation to drought.

In focus group discussions, respondents frequently emphasized the difficulty of obtaining credit facilities as the most significant constraint to the adoption of preferred coping and adaptation strategies as feasible. Most farmers never received credit for crop production or livestock and only 10% received credit from commercial banks, according to the study results (Figure 6.3c). Most commercial banks need security for loan approval and the casual workers or social grant beneficiaries are left out. Figure 3d demonstrates that 43.5% of smallholder farmers do not have financial balances compared with 31% who save their cash in the bank. Most farmers reported that it is hard to save cash in the bank if the balance is insufficient.

6.3.2 Determinants of capacity building of smallholder farmers towards drought

Table 6.1 shows the determinants of capacity building of stallholder farmers in the Vhembe and Mopani districts, Limpopo Province.

Table 6.1: Determinants of capacity building of smallholder farmers towards climate change

Variables	Coefficients	Standard Errors
Age	−0.0265 **	0.0133
Household Size	0.1970 ***	0.0608
Salary	7.6444	275.080
Employment	−6.9432	275.08
Land size	0.1388	0.1191
Borehole	2.5592 ***	0.4832
Social grant	0.8862 **	0.4303
Farming income	1.3554 **	0.5646
Two types of farming	−2.0073 **	0.7915
Three types of farming	−1.6086 **	0.7201
Education status—Grade 12	2.6292 ***	0.5002
Access to dam water	0.3698	0.3610
Constant	−2.1771	1.1973
Summary of the model		
N = 200 Log Likelihood = −77.134 Pseudo R-square = 0.4270	LR Chi-square = 114.94 Prob (Chi-sq) = 0.000	

Source: Author computations. Note: *, ** and *** denote $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively. Variable explanations: Age (Continuous variable); Household size (continuous variable); Salary (dummy variable: 1 = Yes, 0 = No); Employment (dummy variable: 1 = employed, 0 = Not employed); Land size (continuous variable); Access to Borehole (dummy variable: 1 = yes, 0 = No); Access to social grant (dummy variable: 1 = yes, 0 = No); Farming income (dummy variable: 1 = selling, 0 = Not selling); Education-Grade 12 (dummy variable: 1 = yes, 0 = No); Two types of farming (dummy variable: 1 = yes, 0 = No); Three types of farming (dummy variable: 1 = yes, 0 = No); Access to dam water (dummy variable: 1 = yes, 0 = No).

The output of the probit model shows that there are a number of factors that determine the capacity building of smallholder farmers. This is shown by the statistical significance of many variables. According to the results above, age and the type of farming are statistically significant and have a negative coefficient. The age of the farmer is statistically significant at the 5 percent significant level; this means that increasing age reduces the level of capacity building of smallholder farmers to combat drought. It is not surprising that when people become older, their level of work on the farm reduces, hence they are not active enough to build their resilience to drought through agricultural practices such as irrigation, mulching, and others. The type of farming is negative and statistically significant at a 5 percent significant level. This means when the amount of farming increases from two upwards, the farmer becomes less resilient to drought than when focusing on only one type of farming. The increasing number of types of farming may also reduce the resource and needed manpower to build resilience to climate change.

Other factors such as household size, access to boreholes, access to social grants, farming income (produce for sale), and level of education (grade 12) act as positive influences. The household size is statistically significant at the 1 percent significance level showing that increasing the number of members in households increases manpower which can help to build resilience through assisting with the farm. Access to boreholes is significant at a 1 percent level showing that farmers with access to boreholes are getting reliable water as opposed to others and can augment water for irrigation during drought. The social grant is also statistically significant implying that, holding other things constant, farmers with access to social grants are more resilient to drought because they have financial resources to be used during drought or before drought as mitigation and adaptation. Similarly, farming income is also statistically significant (at a 5% level) indicating that farmers producing for sale have financial resources to prepare for drought hence more resilient as compared to their counterparts. The level of education up to grade 12 is statistically significant holding other things constant. This implies that farmers who completed grade 12 (matric) are more resilient to drought than their counterparts. This is not surprising as their level of scientific knowledge is higher, enabling them to think about proper solutions for drought.

6.3.1 Coping and adaptability

The findings showed that extreme drought events are increasing in frequency and intensity and negatively impact smallholder farmers' livelihoods. Weather fluctuations, rising temperatures, and dry spells are some of the impacts of climate change on smallholder farmers. This leads to low crop yields/failed crops. In response to these climatic conditions, smallholder farmers have used different climate-related adaptation strategies to reduce the impacts of climate change. The on-farm adaptation strategies include irrigation, planting early maturing maize varieties, planting drought-resistant crops, changing planting dates, and applying fertilizers; non-farm adaptation strategies include establishing small businesses, casual work, and making local beer (Table 6.2).

Table 6.2: The percentage of smallholder farmers using climate-related adaptation strategies

A strategy for adapting	Greater Giyani (%)	Greater Tzaneen (%)	Thulamela (%)
Irrigation	30	50	70
Early maturing maize varieties	80	70	80
Change in planting dates	45	35	75
Drought resistant crop	60	50	80
Crop diversification	75	60	50
Drilling boreholes	40	30	60
Rainwater harvesting	70	10	40
Mulching to conserve moisture	70	25	50
Application of pesticides	10	10	15
Applying cow dung/chicken manure	15	25	30
Non-farming activities	60	70	30

According to most respondents, part of the desired adaptation strategy is creating strategic feed reserves for livestock, irrigation farming, developing water sources, and establishing livestock insurance and saving plans. Many participants also indicated they would be interested in setting up storage facilities for grain and fodder, improving livestock breeds, making livestock products such as ghee for sale during the dry season, and increasing their herd size. However, households are not free to adopt whatever adaptations and coping strategies they wish. Participants cited several limitations to their strategies, including low incomes and capital, insecurity, illiteracy and a lack of technical knowledge, a lack of finance and access to credit, and insufficient markets and inputs.

Detailed changes in precipitation, heat stress, and Crop Moisture Index (CMI) had been observed in the study areas as illustrated in Table 6.3; this has an impact on crop production and should be considered as part of coping strategies to mitigate risk and build resilience. It is essential to build resilience to combat climate change, as a system should be able to absorb disturbances without crashing (Shikwambana *et al*., 2021; Nhamo *et al*., 2019; Mpandeli *et al*., 2019). A resilient system built up by developing appropriate adaptation and coping strategies at the local level can withstand shocks and rebuild itself in the event of a fundamental shock. The availability and accessibility of technologies and rural support systems as well as the intensity of the climate risks will determine the effectiveness of coping and adaptation strategies (Nhamo *et al*., 2019; Mpandeli *et al*., 2019). Several strategies can be adopted to adapt to climate change, including the adoption of autonomous adaptation such as shifting planting dates and cultivar substitution, embracing technologies such as climate-smart agriculture, addressing livelihood diversification, as well as improving trade policies, and encouraging shifts in diets (Table 6.3).

Table 6.3: Observations of climate change, identifying risks, and adapting accordingly

Observed Changes	Risks That Have Been Identified	Strategy for Coping and Adapting to Drought
Frequent heatwaves	• Water levels in dams, wells, and rivers decline, causing water quality to decline. • Increased water stress in crops. • Increase the risk of disease outbreaks. • The decline in agriculture's output and income has led to an increase in immigration.	• Provision of seeds to support local fodder production. • Provide supplemental feed for cattle as well as mineral feed. • Drought resistant crop and/or animal. • Mulching to conserve moisture.
Reduced rainy season	• Increasing water scarcity leading to water use conflicts in agriculture. • Rainfed production has decreased, especially maize. • A reduction in food production caused by the loss of crops and stock.	• Increasing access to climate information and services. • Use early maturing maize varieties. • Change of planting dates. • Crop diversification. • Use of rainwater harvesting and conservation techniques.
Variability of rainfall within and between seasons	• Increasing water scarcity leading to water use conflicts in agriculture. • Planting date selection. • Loss of income due to extensive agriculture production including vegetables and fruits.	• Use of climate smart agriculture technology. • Change of planting dates. • Crop diversification. • Use of rainwater harvesting and conservation techniques.
Droughts occur more frequently and intensify	• Increased water stress in crops. • Increasing water scarcity leading to water use conflicts in agriculture. • Nature reserves would become less attractive if precipitation declined. • Increase the risk of disease outbreaks.	• Change in planting dates. • Use of rainwater harvesting and conservation techniques. • Drought resistant crop and/or animal. • Crop diversification. • Mulching to conserve moisture.

Further examining this issue through focus group discussions, several of the participants said that some of their preferred strategies require large investment capital up front, which is out of reach for many households, such as establishing irrigation systems and building water supply systems. Adaptation to drought by using improved livestock breeds was stated as an effective adaptation measure, however, affordability of these breeds and the availability of suitable veterinary services remains a challenge due to the poor social and economic status as well as poorly developed markets in the study area.

There is a need to better understand the connection between climate variability and social vulnerability so that this can help guide planning for increasing coping and adaptation of communities to current and future droughts. Several climate-smart innovation strategies are recommended, including greenhouses and hydroponics. These innovations are usually supported by government subsidies and loans. To successfully implement drought relief programs, governments must develop inter-governmental relations, strengthen research institutes, and utilize ICTs and social networks through investments in rural ICT infrastructure, broadband, and the development of affordable, user-friendly applications, as well as training public extension and advisory services. Planning for the emergence of cohesive strategies that are geared towards resilience and sustainability occurs as the result of transformative and dynamic processes within a socio-ecological system. Figure 6.4 illustrates the current concepts of coping and adaptation to a proper planning guide for increasing coping and adaptation.

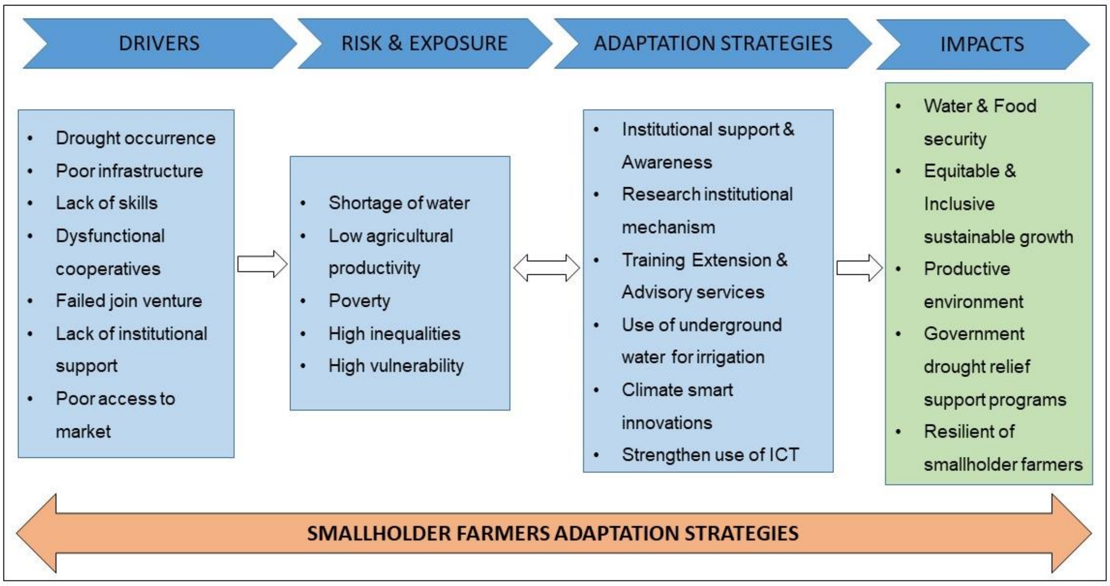


Figure 6.4: Policy-relevant adaptation strategies for forming coherent policies

6.3.2 Dependency upon government support during drought

To assist all provincial governments in managing the drought, the national government has developed a drought management strategy. Depending on their specific needs, these provinces must then create their own programs. Moreover, metropolitan and district municipalities have a responsibility to set up and implement a framework for disaster management within their jurisdictions that meets uniform and integrated demands of disaster management in the region where they are located. The studies of drought assistance researchers show a consensus amongst analysts that, even though the government has provided drought relief for a few years, the assistance has been ineffective, poorly coordinated, and untimely (Ngaka, 2012). In the research, there is an overemphasis on the chances and coping mechanisms, but not enough emphasis on how they impact the situation.

A study conducted by Rukema (2013), who also examined drought, people's resilience, and their ability to withstand disasters in the Msinga Local Municipality in Kwa Zulu-Natal, recommended ensuring that any financial or bureaucratic bottlenecks are removed to ensure program outreach occurs on schedule. Furthermore, disaster risk management should involve non-government organizations and community-based organizations.

Although the study found that smallholder farmers did not have enough independence when it came to dealing with hardships caused by the drought, it acknowledged that the most effective coping mechanisms were possible when drought planning was undertaken. Farming was inadequately assisted during a recent drought from 2014 to 2016. The cattle owners too had to provide validation documents, in addition to the long queues and strict requirements. The findings revealed that not every cattle owner possessed brand mark certificates or cattle dipping records. Due to this, some owners gave up trying to meet these demands, forfeiting needed assistance. Climate change can significantly impact cattle owners due to poor planning and management, which leads to a high dependence on government support.

6.3.5 Extension services to increase drought-resilience

Participants cite extension advisory services as crucial for smallholder farmers to cope and adapt to drought. Smallholder farmers remain among the main beneficiaries of support services in the agricultural sector, for purposes of rural development, commercialization, food security, poverty reduction, and income generation. Smallholder farmers who have access to sufficient farmer support services are better equipped to cope with droughts and boost farm income. Approximately 70 percent of farmers lacked access to extension services, with only 30 percent receiving crop production information through extension services. The agricultural extension services in South Africa are challenged with improving food security, creating sustainable employment, and developing rural areas through increased agricultural production (Baah *et al*., 2009).

As a result of several barriers contributing to the inefficiency of the management of droughts, agricultural advisors in the study areas pointed to the lack of resources, in particular in the transport of officers. Most smallholder farmers are located far from the district office or service centers where most of the agricultural advisors tend to live. Hence, agricultural advisors require transport to get to the farming areas. Regrettably, many agricultural advisors do not have their own means of transport, and this has a direct impact on the role of extension advisory to reach vulnerable smallholder farmers in providing drought-related advice, it undermines the delivery of information to support effective adaptation and coping. This finding is in line with previous studies in Ghana, which revealed a lack of transportation to farming communities is a major obstacle to agricultural extension officers feeling motivated to perform their duties (Baah *et al*., 2009). According to Belay & Abebaw (2004), agricultural extension officers in southwestern Ethiopia stated that the lack of transportation facilities significantly hampers their efforts to disseminate information regarding modern agricultural technologies.

Another barrier for smallholder farmers to access extension services is the low agricultural advisors to farmer ratio. Fanadzo & Ncube (2018) reported that the ratio of extension officers to farmers in South Africa is 1:878. The President of South Africa during the 2021 State of the Nation Address (SONA) in Parliament said the government is planning to recruit over 10,000 extension officers to reduce the ratio of extension to farmer ratio to 1:250. When he delivered his budget speech two weeks later, the Minister of Finance reiterated the same sentiments. The high ratio of extension officers to farmers increases the workload for agricultural advisors which could potentially cause agricultural advisors to lack time to acquire skills and competencies to cope and adapt to drought, particularly in dryland farming systems. Our findings agree with previous studies that found that only about one out of every 1000 farmers have access to frontline extension workers in Kenya, compared to a required one out of every 400 (Ifejika Speranza *et al*., 2009). According to Chenseu *et al*. (2019), although 93% of their participants say their sections have extension officers, only 25% of their participants reported receiving an extension visit every month, and 22% only received one in the complete cropping season. This is a worrying factor because vulnerable smallholder farmers need the necessary technical understanding of adaptations to cope and adapt to drought.

Participants gave different answers in response to a question about support services. According to the sampled farmers, 70% do not receive any support services and rely on their own resources. Adaptation methods can only be implemented if there is adequate funding to fund drought coping and adaptation strategies. Previous studies have noted that it is difficult for smallholder farmers to implement adaptation strategies recommended by agricultural advisors because of insufficient funding (Ebenehi *et al*., 2018; Swanson, 2008). Smallholder farmers are often required to make financial commitments to drought adaptation and coping strategies, which include planting drought-tolerant varieties of crops and early maturing breeds of crops. Poor credit conditions make adaptation measures impossible, thus aggravating poverty. Due to this, farmers have a difficult time adopting adaptation strategies and implementing interventions that reduce their vulnerability through other agricultural innovations in the face of climate change.

Agricultural advisors similarly highlighted that there is some reluctance among farmers to adopt new technologies and innovations that can help them to cope and adapt to drought. Smallholder farmers are using their traditional farming methods. Nevertheless, improved agricultural farming can assist smallholders to decrease their vulnerability to drought when adopted as advised by agricultural advisors. Many smallholder farmers find it difficult to abandon older practices due to social beliefs and values (Meiker *et al*., 2015). In their study of agricultural technologies' adoption, Meijer *et al*. (2015) report that both extrinsic and intrinsic variables contribute to adopters of agricultural innovations' behavior, knowledge, attitudes, and perceptions. Farmers' resistance to change is linked to a general lack of trust in science, largely due to past failures in predicting the weather and innovations that did not meet their expectations (Kabobah *et al*., 2018).

The majority of smallholder farmers in Limpopo Province desire visits from agricultural advisors for information concerning climate change impacts such as drought, which are often presented in scientific language and therefore difficult to understand (Smith *et al*., 2021). A farmer's most important source of information is the agricultural extension. Research indicates that farmers with access to good quality extension services and technical information are better prepared to cope and adapt to drought (Carlisle, 2016).

6.4 Conclusions

A majority of drought-resilient strategies are reactive and typically intensify the use of existing resources, which may, in turn, undermine the lives of those they are intended to benefit/relieve. Smallholder farmers have used different climate-related adaptation strategies to reduce the impacts of climate change. The adaptation strategies include irrigation, planting early maturing maize varieties, planting drought-resistant crops, changing planting dates, small businesses, and casual work. A number of socioeconomic developments and deteriorating ecological conditions limit opportunities for long-term drought adaptation strategies. Lack of farmer education to understand climatic variability, poor management, lack of farming skills, difficulties accessing formal markets for remunerative crops, high transportation costs, lack of market information, and inadequate government support are the main factors. There are likewise high levels of dependence on government drought relief support among smallholder farmers in the Limpopo Province as they lack a well-structured risk mitigation plan. In order to address common challenges associated with climate change adaptation, institutions working with smallholder farmers need to be well coordinated. To successfully implement important alternative technologies, young educated farmers must be targeted; the main issues contributing to non-adoption, such as drought warnings, must be addressed. National and Provincial governments must invest resources in strengthening adaptive leadership and building capacity to be better prepared for the drought.

6.5 Recommendations

The study recommends that extension officers and other stakeholders in the agricultural sector continue to empower smallholder farmers to resist the effects of climate change, especially since they are often negatively affected by it. Farmers' ability to perceive and adopt agricultural innovations such as climate change adaptations can be improved greatly by adequate access to extension services. As a result, proactive measures should be taken to protect the main assets, such as pastures and livestock. As communities become more aware of climate change, they should better understand how to use the limited resources they possess to build more resilient communities. To ensure science and policy interfaces function correctly, there are several elements that need to be addressed, including capacity building, technological demonstrations, and greater dissemination of knowledge. The study recommends the use of rainwater harvesting to conserve water during drought periods and alternative irrigation. It may be argued that during severe droughts, there may be few days of rain so the amount of water available for harvesting may be inadequate. A plan could be made to bring in water trucks to fill tanks. Additionally, without alternative irrigation water sources, agriculture will be threatened in the long run, and households will have to find other livelihoods for themselves if the issue persists.

CHAPTER SEVEN

CLASSIFICATION OF SMALLHOLDER FARMERS ACCORDING TO LIVELIHOODS COPING STRATEGIES AND LIVELIHOOD OUTCOMES IN THE MOPANI AND VHEMBE DISTRICTS, LIMPOPO PROVINCE

Part of this chapter will be submitted for publication in the International Journal of Disaster Risk Reduction

Abstract

Drought poses significant challenges to agricultural communities around the world, affecting both food security and livelihoods. Smallholder farmers, often relying heavily on rain-fed agriculture and are particularly vulnerable to the impacts of drought. In this paper, classifications of smallholder agricultural activities to the prevailing changing climatic conditions were formulated in such a way that recognizes different categories of smallholder farmers. The classifications were formulated according to the livelihoods and resource endowment of each local area to meet specific needs. A total of 200 interviews were conducted with smallholder farmers in the Mopani and Vhembe districts of the Limpopo Province. The study used the concept of the Household Economy Approach (HEA), Socio-economic characteristics and Livelihood activities to characterise and classify smallholder farmers in the districts using socio-economic, geographic, and ecological factors. The key factors that underpin the classification of smallholder farmers and determine livelihood strategies include sources of income, level of education, National social grants, production activities, tangible assets, household characteristics and other factors. The results demonstrated that much diversification exists inside smallholder farmers, conveying more resilient strategies towards livelihood outcomes. In terms of living standards, food consumption, asset attainment, and lower prevalence of food insecurity, those with higher education, working and have access to bank loans have better livelihood strategies. This research contributes to the effort to better document and understand farmers' livelihoods coping strategies and livelihood outcomes in coping with drought through qualitative research methods and from the perspective of the individual smallholder farmer, which is important for making context-specific policy and project recommendations aimed at smallholder farmers.

Keywords: Smallholder farmer, livelihood activities, classification, Household Economy Approach, Socio-economic characteristics

7.1 Introduction

As a result of small holder farmers' limited infrastructure and inputs to protect them from frequent droughts, smallholder farmers are often considered more vulnerable than commercial farmers, narrow yield margins, and susceptibility to market fluctuations (Shikwambana *et al*., 2021; Brown & Funk, 2008). There are various categories of smallholder farmers who require different types of support in agricultural development strategies. The management of resources is complicated by frequent droughts, which call for on-going adaptation and coping strategies (Sabates-Wheeler *et al*., 2008).

Health, education, infrastructure, political participation, and poverty are considered social variables that affect the vulnerability of smallholder farmers (Shikwambana *et al*., 2021; Brooks *et al*., 2005). From social to financial assets, all of these factors may indicate access to resources (Shikwambana & Malaza, 2022; Blaikie *et al*., 1994). Smallholder farmers' vulnerability is determined by their access to resources and their entitlement to use these resources (Shikwambana *et al*., 2021). Resources are distributed based on social processes, which makes certain groups more vulnerable to risk and less capable of adapting (Smit & Wandel, 2006; Adger *et al*., 2004). Thus, enabling resources access will improve the adaptive capacity and reduce the vulnerability of smallholder farmers.

Climate change's impact on rural livelihoods and how households cope with and adapt to it has been described in literature on rural livelihoods (Bryan *et al*., 2009; Osbahr *et al*., 2008; Paavola, 2008; Reid & Vogel, 2006). A number of factors, such as economic globalization and environmental change, interact with adaptation as a result of multiple stressors (Belliveau *et al*., 2006; Eakin, 2005). In urban disaster literature, improved household access to housing, education, and other resources has been shown to reduce poverty and disaster risk by meeting basic needs and buffering against stress (Moser & Satterthwaite, 2009; Sanderson, 2000). Rural adaptation to multiple stressors, however, requires further research to understand their complex asset-based relationship.

Pienaar & Traub (2015) proposed that typologies can be used as key to comprehend the changes farming undergoes including output levels, employment rates, the farming intensity, and the policy reforms. The typology of the sustainable livelihoods approach seeks to classify rural livelihood diversification among rural households, including agricultural activities, economic, social, environmental, and political perspectives (Pienaar & Traub, 2015). In addition, classifying farmers into different categories can be a useful method to unpack and understand the wide diversity among the farms, resulting to clear and understand approaches which should be specific livelihood targeted (Chikowo *et al*., 2014).

One might argue that supporting smallholder farmers can be in their quest for improving themselves, livelihood outcomes and others can be done by rural livelihoods analysing to get a clear picture of the livelihood strategies. Specific smallholder farm strategies can be enhanced by livelihood approaches to these smallholder farmer supports. All this can be achieved by means of proper characterization, classification as well as differentiation of these different smallholder farmers, which can be done by developing farmer typologies. Smallholder farmers could be classified according to livelihood strategies, assets possessed or sole purpose for production. The main objective of the study was to classify the various types of smallholder farmers according to their livelihood strategies and livelihood outcomes in the Mopani and Vhembe districts of the Limpopo Province. The point is to distinguish homogenous farming households and their ability to naturally choose different livelihood strategies to acquire better living standards.

7.2 Material and methods

7.2.1 Data collection

The study gathered both primary and secondary data to accomplish the research objectives and to answer the research questions. Primary data was gathered through questionnaires which included close and open-ended questions, and secondary data was acquired through published journal articles. A total of 200 farmers took part in the qualitative interviews. Households were selected using convenience sampling methods, and households were selected that met basic criteria including that they practiced agriculture, were easily accessible to the researcher, and were willing to participate (Randall and Phoenix, 2009).

As a way to examine participants' livelihood strategies, the Department for International Development (DFID)'s Sustainable Livelihood Framework was used to develop a semi-structured questionnaire to gather information on smallholder farmer assets and general livelihoods. Physical, human, financial, social, and natural assets made up the five main types of livelihood assets outlined in the questionnaire. Participants were assisted in completing the questionnaires in the study area, and questionnaires were distributed to all sampled households. The Limpopo Department of Agriculture and Rural Development (LDARD) conveyed their Extension Officers to aid both moving towards the participants to evoke their interest and administration of the questionnaires.

Focus group discussions and key informant interviews were used to collect local level data about wealth, food and income sources, spending patterns, bad year coping strategies, and seasonal calendars. A wealth classification of the smallholder farmers was made according to how they can exploit the available options within a given area. The smallholder farmers were classified as indigent, middle or better-off. Communities in zones classified as indigent will have difficulty coping with hazards, communities in middle-class zones can cope to a certain extent, and those in better off areas can cope better.

The secondary data were obtained from other sources such as the Department of Agriculture for maps of cultivated fields and coordinates for target smallholder farms. Soil and climate data will be obtained from government smallholder farmer intervention programme databases such as the Comprehensive Agricultural Support Programme (CASP). The academic and government research publication were also used as a secondary data.

7.2.2 Data analysis

The data from the interviews were compiled into spreadsheets and analysed in Statistical Package for the Social Sciences software (SPSS). An analysis of the assets of smallholder farmers was carried out according to their categories (five types of assets). It was most important to determine what assets the smallholder farmers possessed and how they translated these into livelihood strategy. Data was captured and analysed without identifying respondents because completed questionnaires were numbered accordingly. The main characteristics of farming household systems were described variable per variable. The main information in the database used for the typology building is family characteristics, manpower, household income, agricultural practices, access to services, and assets ownership.

7.2.3 Sustainable livelihood approach

A wide range of theories have been utilized as a framework to create farm typologies which include farming styles, sustainable livelihoods, farming context and market structure (Perret *et al*., 2005). In this study, sustainable livelihoods is the theoretical framework, a multi-disciplinary approach considering the economic, social, environmental, and political aspects of agriculture (Scoones, 2009). As poverty reduction thinking evolves, and poverty people's lives and structural and institutional issues become more important, this approach is based on the ever-changing thinking of poverty reduction. The researcher conception of farming systems is based on the Sustainable Livelihood approach used by DFID (DFID, 1999) (Figure 7.1).

The sustainable livelihoods framework is a push to conceptualize livelihoods comprehensively, catching the numerous complexities of livelihoods, and the imperatives and openings that they are subjected to. These requirements and openings are formed by various components, extending from worldwide or national level patterns and structures over which people have no control, and may not know about, to more nearby standards and establishments and, at long last, the resources for which the family units or individual has coordinate access. Until further notice, the researcher will utilize the household as a unit of investigation. It is vital to perceive that not all people inside a household unit have level with basic leadership power, or advantage similarly from household unit resources or salary.

Smallholder farmers' impacts of drought are best understood by analysing local livelihoods, which is essential for understanding how hazards such as drought and crop failure impact them (Selvaraju *et al*., 2006). A livelihood is the sum of ways in which people make their living (Lawrence *et al*., 2007). Therefore, an understanding of livelihoods enables understanding the level and kind of impact likely to be faced by the smallholder farmers in the Limpopo Province in case of drought and diminished water resources. A household typology is used in this study to illustrate how household water resources contribute to their livelihood strategies and how they use them. Using the data, you can formulate recommendations tailored to each user category on how to use and manage water.

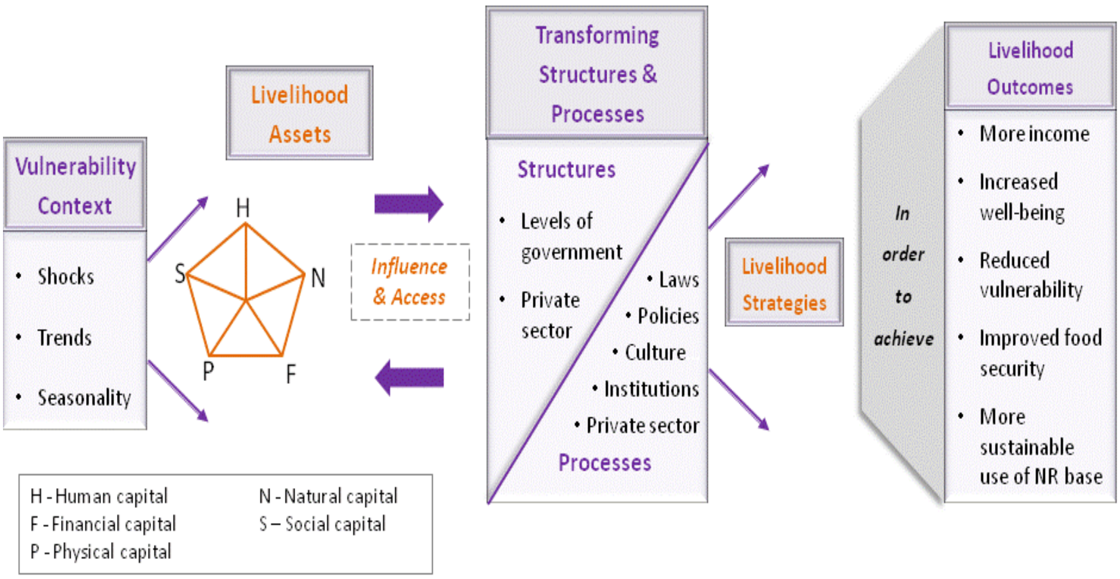


Figure 7.1: Sustainable Livelihood Theoretical Framework

(Adapted from DFID, 1999)

7.3 Results and discussion

7.3.1 Socio-economic characteristics

Access to assets is a key feature in the composition of rural household agricultural production and empowers smallholder farmers to overcome shocks such as droughts. The more assets a household has, the more chances it has of successfully coping and adapting to drought without sinking into the poverty trap (UNDP, 2006). Access to land was a key feature which would help establish whether a household will be able to produce food for both subsistence and marketing during drought periods.

This study found that most farmers cultivate at both their residence and other sites located away from their residence. As previous research has shown, smallholder production is mainly the result of households working on smaller plots of land with limited resources for household needs, and lesser resources for extra income or sales (Shikwambana & Malaza, 2022). The land is also of a poor quality and very few smallholder farmers derive a significant part of their income from agricultural activities.

There is a significant impact of climate change on water resources across the districts under study, thus affecting a variety of sectors. Identifying available resources for their farming has also been discussed in the study. Since droughts and floods lead to extreme unreliability of rainfall, groundwater is a critical resource for intensifying irrigation and making use of the vast and untapped groundwater resource. Water challenges are prevalent in the study areas, especially Greater Giyani, and smallholder farmers' success is heavily influenced by water.

The research findings indicated that 63.5% of the farmers rely on rainfall for crop production and livestock while 21.5% have boreholes within the premises they reside on (Figure 7.2). As a result, their farming outputs are low and they are mostly seasonal, which explains their low productivity. In order to grow their preferred crops or farm, they wait for the right season.

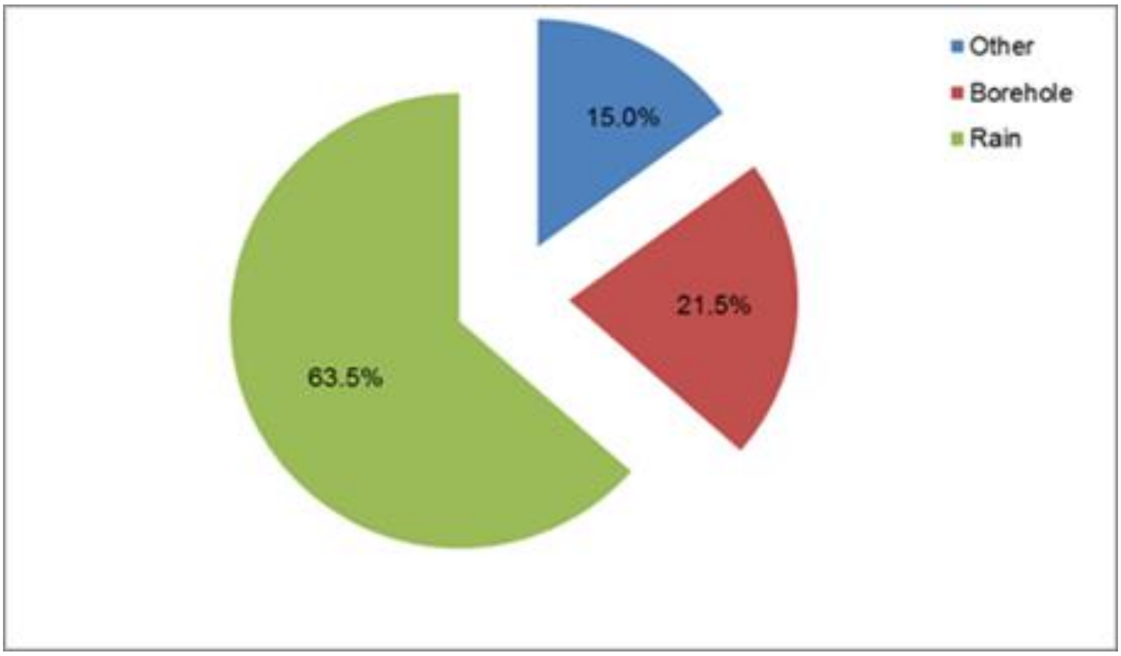


Figure 7.2: Percentage of smallholder farmers livelihood classification in Mopani and Vhembe districts (*n* = 200)

One of the most critical difficulties facing the viability of smallholder farmers in the Limpopo Province is the access of credit, intensified by poor linkages to markets. In the commercial banking system, only 9.5% of farmers can obtain credit. A commercial bank typically requires security for loan approval, so casual workers and individuals receiving social security benefits are excluded. According to the results, respondents who were employed casually or temporal jobs were mostly involved in public works such as the Expanded Public Works Programme (EPWP) and other projects in the area. The access of smallholder farmers to extension services remains one of the most important interventions in the agricultural sector for rural development. Extension services help smallholder farmers commercialize their crops, ensure food security, alleviate poverty, and generate income. The study found that 72% of farmers lacked access to extension services, while only 28% received crop production advice from extension agents (Figure 7.3).

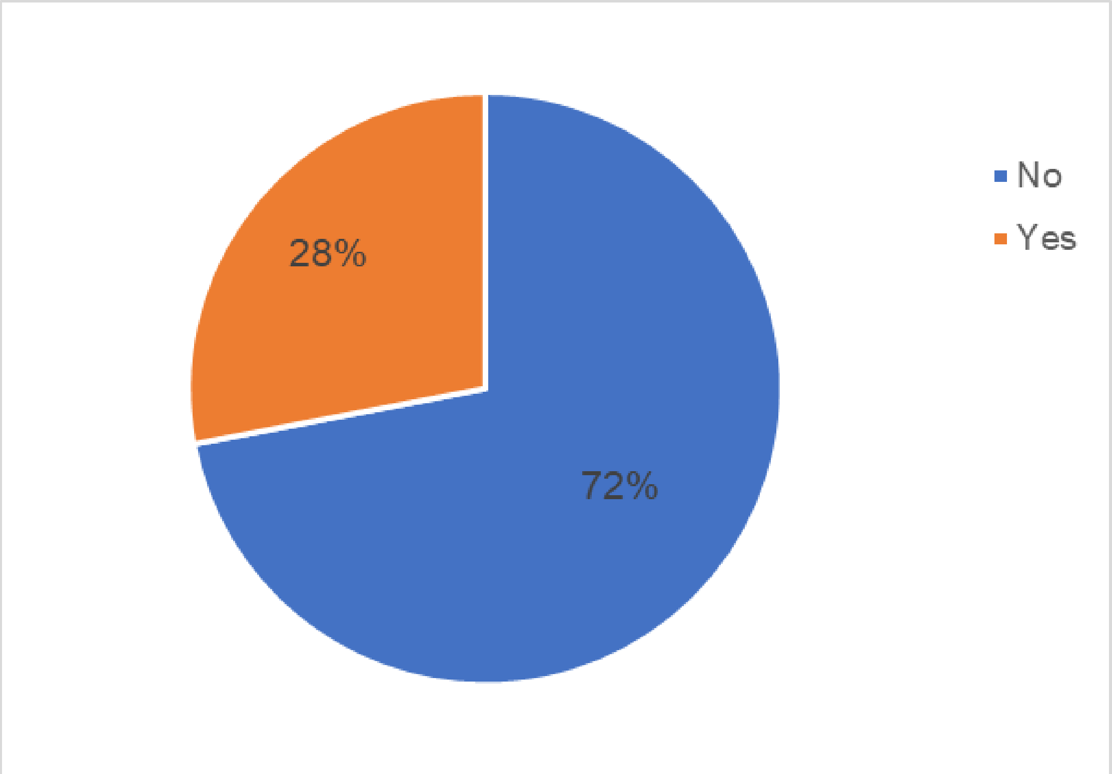


Figure 7.3: Percentage of smallholder farmers access to extension services in the Mopani and Vhembe districts (*n* = 200)

Smallholder farmers in the two districts are further limited by lack of access to mechanization. The tradition of using draught animal power in the Limpopo Province has vanished and most farmers use heavy equipment for ploughing and land preparation, spraying and harvesting. Smallholder farmers who own tractors and implements are regarded as better-off farmers. They also own a lot of livestock which provides drought power. Ownership of livestock such as cattle is instrumental in enabling timely cultivation of crops especially within the context of rain fed agriculture. Farmers need enough cattle to form a span for draught power. Cattle ownership was tilted in favour of male-headed households. Women tended to have ownership and control of smaller livestock such as goats and chicken. Ownership access and utilization of all five pillars of capital is summarized in Table 7.1.

Table 7.1: Utilization of the five pillars of capital based on analysed data and community perceptions

Level of ownership access and utilization of the five pillars of capital		DFID Sustainable Livelihoods Framework – Five Pillars of Capital		
		Indigent (50-60%)	Middle (30-40%)	Better-Off (10%)
Natural Capital (Land, water source, adequate rainfall etc)	High			
	Moderate		✓	✓
	Low	✓		
Physical Capital (Infrastructure, roads, communication markets etc)	High			✓
	Moderate		✓	
	Low	✓		
Financial Capital (Livestock, cash savings, access to credits etc)	High			
	Moderate		✓	✓
	Low	✓		
Human Capital (Types of labour, education, family size etc)	High			✓
	Moderate		✓	
	Low	✓		
Social Capital (Social networks, gifts, relief aid etc)	High			
	Moderate		✓	✓
	Low	✓		

7.3.2 Model development

A model for predicting annual income of smallholder farmers was formulated in this study. The annual income (*Y*) of a smallholder farmer was modelled as a linear combination of the socio-economic factors (X_i). The following variables were used in the calculation:

7.3.2.1 Farm size (X_1) (in hectares)

Farm size in this study, refers to the total area of land owned or operated by the smallholder farmer for agricultural purposes measured in hectares (ha). These are typically small family farms with relatively limited land holdings which can range from less than 1 hectare to a few hectares.

7.3.2.2 Crop diversity index (X_2) (a value between 0 and 1)

The Crop Diversity Index (CDI) is a measure used in agriculture to assess the variety of crops grown on a farm. It quantifies the number of different crop species or varieties cultivated within a defined area. The calculation of a crop diversity index involved counting the number of different crop species or varieties and took into account the relative abundance or area dedicated to each crop. The Shannon-Wiener Diversity Index, which consider both the number of species and their relative abundance was used in the study and formulated as below (Equation 7.1)

$$\text{CDI} = \frac{\sum_{i=1}^{n} p_i^2}{N} \qquad \textbf{Equation 7.1}$$

Where:

n is the total number of different crop species or varieties observed.

p_i represents the proportion or area covered by the $_{it}$h crop species or variety.

N is the total area under cultivation, or the total number of crops observed.

7.3.2.3 Livestock Unit Index (X_3)

The Livestock Unit Index (LUI) is a measure used to quantify and compare the total livestock holdings of a farm by standardizing different types of livestock into a common unit. The LUI helped in assessing the overall livestock diversity and its impact on a farm's socio-economic characteristics. To create a Livestock Unit Index (Equation 7.2), standard values called "Livestock Units" (LUs) were assigned to each type of livestock based on their relative size and feed requirements.

$$\text{LUI} = \frac{Total\ livestock\ units\ (TLU)}{Total\ number\ of\ livestock\ types}$$ **Equation 7.2**

Where:

LUI is the Livestock Unit Index.

Total Livestock Units (TLU) is the sum of the Livestock Units (LUs) for each type of livestock on the farm.

Total Number of Livestock Types is the count of different types or species of livestock included in the calculation.

7.3.2.4 Education Index (X_4)

The Education Index (EI) was used to assess the educational attainment and access to education of the small holder farmers to provide insights into the education-related achievements and opportunities within the farmers. The Education Index considered two main components: access to education (enrolment and attendance) and educational attainment (years of schooling or educational qualifications) (Equation 7.3). A higher Education Index value indicates better educational opportunities and achievements. Access to Education and Educational Attainment are values between 0 and 1, where 1 represents the highest level of access or attainment and 0 represents the lowest.

$$\text{EI} = \sqrt{Education\ attainment\ component + Access\ to\ eduaction\ component}$$ **Equation 7.3**

Where:

Educational Attainment Component: mean years of schooling (Educational Attainment) normalised to a scale between 0 and 1 using a theoretical maximum value (e.g., 15 years, which represents a high level of education).

Access to Education Component**:** the geometric mean of the primary and secondary gross enrolment rates. The geometric mean is used to ensure that lower values in either component have a significant impact on the overall index.

Access to Education and Educational Attainment are values between 0 and 1, where 1 represents the highest level of access or attainment and 0 represents the lowest.

7.3.2.5 Access to Resources Index (X_5)

The Access to Resources Index (ARI) is used to assess the availability and accessibility of essential resources that can significantly impact the socio-economic well-being of the farmers (Equation 7.4). The specific resources included in the index varies depending on the context and the objectives of the assessment. Common components of an Access to Resources Index for small holder farmers included access to land, water, healthcare, credit, technology, and other critical resources.

$$\text{ARI} = \frac{(Access\ to\ land\ component + Access\ to\ credit\ component)}{2}$$ **Equation 7.4**

Access to Access to Resources Index are values between 0 and 1, where 1 represents the highest literacy of the farmers and 0 represents the lowest.

Where:

Access to Land Component: is the normalised percentage of farming households with secure land tenure to a scale between 0 and 1.

Access to Credit Component: is the normalize percentage of farming households with access to formal credit to a scale between 0 and 1.

7.3.2.6 Distance to market index (X_6)

The Distance to Market Index (DMI) is a metric that was used to assess the proximity of a location (such as a rural community or farm) to various types of markets, which can include urban centres, wholesale markets, retail markets, or other key economic centres. The index provides insights into the ease of access to markets, which can be critical for determining transportation costs, market opportunities, and overall economic well-being (Equation 7.5).

$$\text{DMI} = \frac{(Distance\ to\ urban\ centre\ component + Distance\ to\ wholesate\ market\ component)}{2}$$ **Equation 7.5**

Where:

Distance to Urban Centre Component: is the normalized distance to the urban centre to a scale between 0 and 1 (assuming a theoretical maximum distance).

Distance to Wholesale Market Component: is the normalised the distance to the wholesale market to a scale between 0 and 1 (assuming a theoretical maximum distance):

The Distance to Market Index are values between 0 and 1, where 1 represents the further to markets and 0 represents closer to markets.

7.3.2.7 Household size index (X_7)

The Household Size Index (HIS) is a metric that was used to assess and quantify the size of households of farmers. It provided insights into the demographic characteristics of households, particularly the number of individuals living in each household. This index was used to understand family structures, resource allocation, and socio-economic dynamics (Equation 7.6).

$$\text{HSI} = \frac{Average\ household\ size}{Maximum\ household\ size}$$ **Equation 7.6**

Where:

Household Size Component: the average household size for the population based on the household size data. This can be done by summing the sizes of all households and dividing by the total number of households.

Household Size Index Calculation: the normalised average household size to a scale between 0 and 1, where a higher value indicates larger households.

The average household size is normalised to a scale between 0 and 1, where a higher value indicates larger households.

7.3.2.8 Access to credit index (X_8)

The Access to Credit Index (ACI) is a metric used to assess the extent to which the farmers' households have access to financial credit or loans. This index helps in evaluating the availability of financial resources and the ease with which individuals or entities can obtain credit, which can significantly impact economic activities, investment, and overall financial well-being (Equation 7.7).

$$\text{ACI} = \frac{Credit\ access\ component + Intrest\ rate\ component}{2}$$ **Equation 7.7**

Where:

Credit Access Component: is the normalised the percentage of eligible farmers with access to credit sources to a scale between 0 and 1 (assuming a theoretical maximum).

Interest Rate Component: weighted average of interest rates from formal and informal credit sources, considering the percentage of credit access from each source.

The credit access and interest rate components are normalised to a scale between 0 and 1, where a higher value indicates better credit access.

7.3.2.9 Model: predicting annual income of smallholder farmers

Using the variables as explained above, the income (Y) of a smallholder farmer can be modelled as a linear combination of the socio-economic factors (X_i) as seen in Equation 7.8.

$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+\varepsilon$

$$Y = \beta_0 + \sum_{i=1}^{8} \beta_i X_i + \varepsilon$$ **Equation 7.8**

Where:

β_0 is the intercept.

$\beta_1, \beta_2, \dots, \beta_8$ are the coefficients representing the impact of each socio-economic factor on income.

ε is the error term representing unexplained variation.

The coefficients β_i can be estimated through regression analysis using historical data on smallholder farmers. For example, the coefficient β_1 represents how much the income changes for a one-unit increase in farm size while keeping other factors constant. Similarly, β_2 to β_8 represent the impact of other socio-economic factors on income.

7.3.3 Livelihood activities

In livelihood analysis, the household socio-economic have a significant influence in getting decent variety and have routinely been incorporated into typology research. Social relations such as gender, class and other social differences is a key to livelihood analysis as these administer the dispersion of salary, work, utilization, and accumulation dynamics and will in this way be incorporated into the typology. Other significant factors incorporate the age, level of education, and marital status of the head of the family. These factors matter as an employment incorporates social and connection systems for encouraging various salary portfolios, just as gender.

Household income is normally a significant determinant of livelihood diversification. The primary income sources utilized in the analysis incorporates, salaries, social grants, and remittance payments. Total income is likewise included as some assistant livelihoods; together with the fundamental main income sources show the family's money related position, while per capita nourishment use gives a sign of the use differences in food utilization. The variables incorporated into this segment features key imperatives and choices families face concerning their financial and welfare results. In addition to food security and access to credit, the analysis also considers resource status and resource availability. The variables included to gauge the households' farming orientation are restricted to the questions asked in the survey. Family members who work on the farm, the hectares of land used for farming, the number of dairy cattle, sheep, and goats, and chickens the family owns, and its month-to-month expenditures on inputs are all variables to consider when calculating production.

7.3.3.1 Access to assets (natural capital) for smallholder farmers

Assets or capitals are stores of wealth that a household owns and can draw from in order to construct a livelihood system (Ellis, 2000). Forms of capital include natural, physical, human, financial and social (Ellis, 2000).

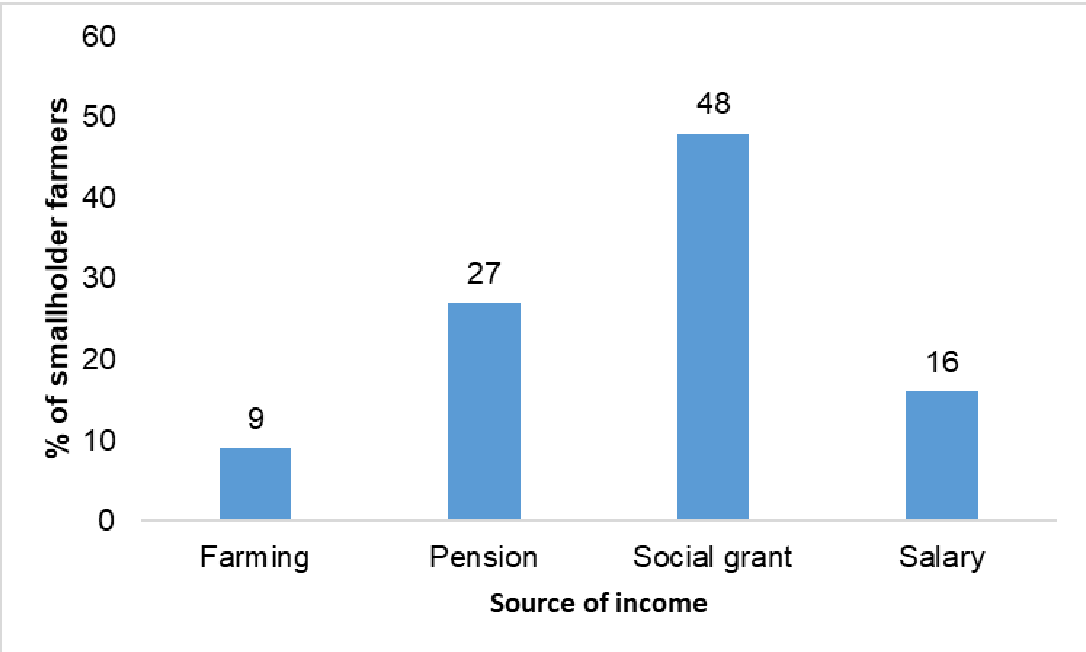


Figure 7.4: Types of capital accessed by smallholder farmers in the Mopani and Vhembe districts (*n* = 200)

Natural capital is the stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to provide benefits to people (Bateman & Mace, 2020). All the farmers had access to land for grazing in communal areas. Out of the cultivation area used by the respondents, 32% of the land is less than 1ha while 48% cultivate on land between 1ha and 4ha (Figure 7.5).

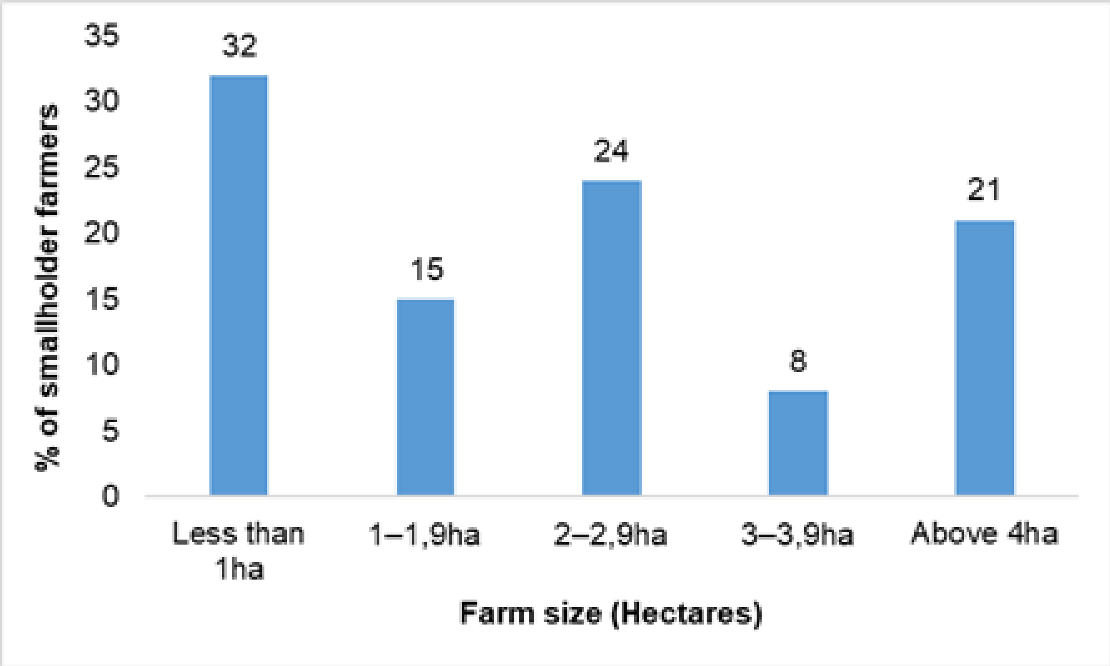


Figure 7.5: Percentage of smallholder farmers land size in Mopani and Vhembe districts (*n* = 200)

7.3.3.2 Access to assets (human capital) for smallholder farmers

According to the Worldbank (2020), the Human Capital Index (HCI) of South Africa is higher than the average for Sub-Saharan Africa region but lower than the average for Upper middle-income countries. Between 2010 and 2020, the HCI value for South Africa remained approximately the same at 0.43. The Government of South Africa has invested in education infrastructure and has improved participation in all levels of education, from primary to tertiary. However, our livelihood survey showed that 32% of the households in the study areas had not attended school. 40% of the respondents stated that they had not completed primary level education, 17% of the respondents claimed to have reached high school, while only 11% had claimed to have reached tertiary level of education (Figure 7.6).

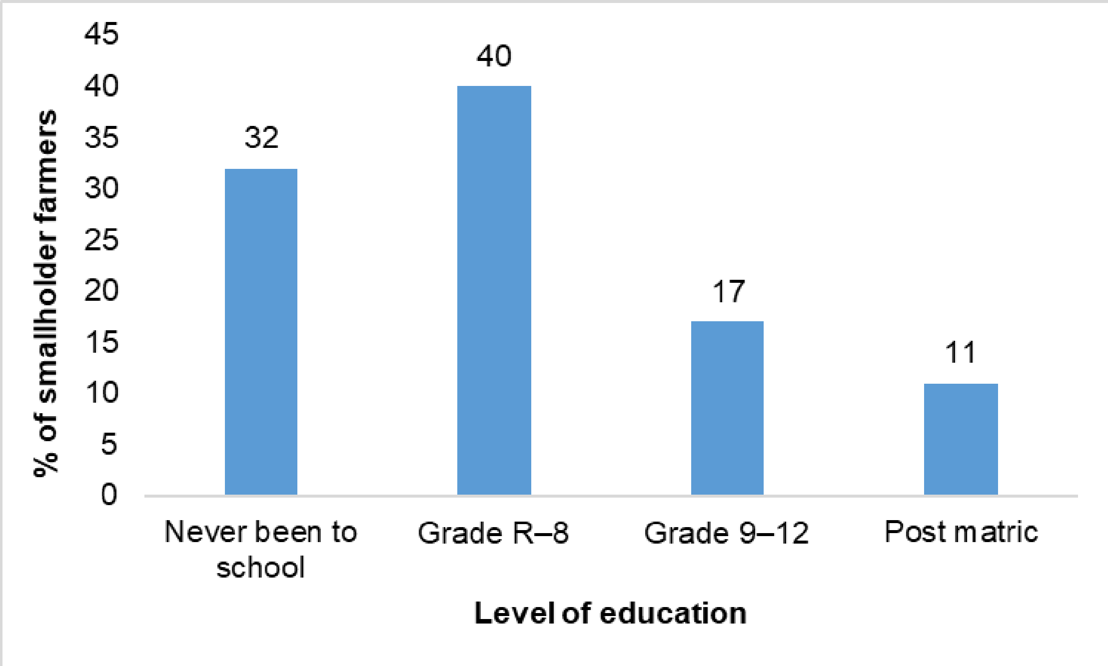


Figure 7.6: Level of education by smallholder farmers in the Mopani and Vhembe districts (*n* = 200)

7.3.3.3 Access to assets (financial capital) for smallholder farmers

To determine the various sources of financial capital in the livelihood survey, farmers were asked where they would seek help when faced with financial problems. It was surprising that over 90% of the farmers indicated that they do have access to credits mostly from government and financial institutions (Figure 7.7).

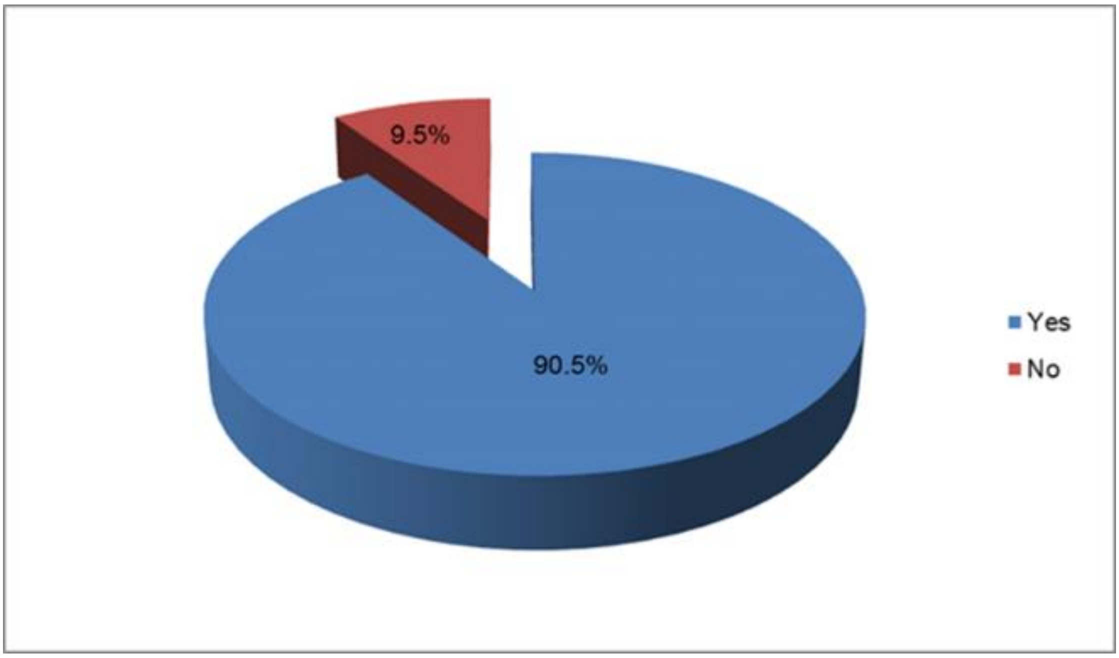


Figure 7.7: Access to credit by smallholder farmers in the Mopani and Vhembe districts (*n* = 200)

7.3.3.4 Access to assets (social capital) for smallholder farmers

To determine the different variables of social activities of social capital in the livelihood survey, farmers were asked if they belong to the farming groups. It was surprising that over 70% of the farmers indicated that they belong to the farming group and meet monthly to discuss the farming activities (Figure 7.8).

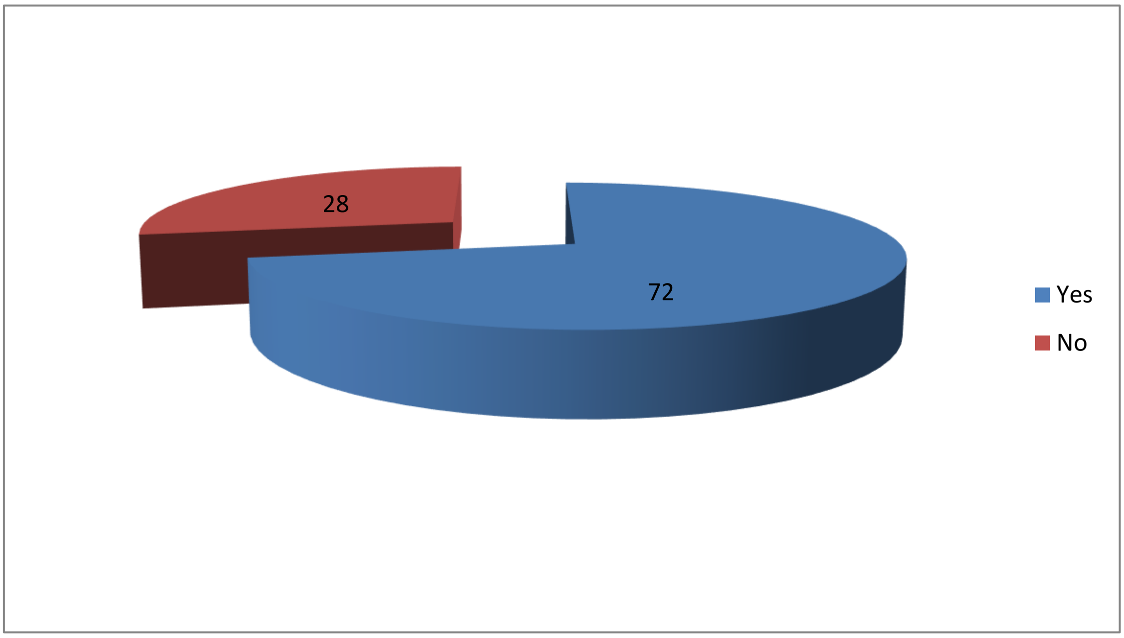


Figure 7.8: Smallholder farmers belong to the group in the Mopani and Vhembe districts (*n* = 200)

7.3.3.5 Access to assets (physical capital) for smallholder farmers

To determine the transportation cost of physical capital in the livelihood survey, farmers were asked which mode of transport they uses. 60% does not have their own transport and they rely on public transport. With the ever rising of public transport fee, smallholder farmers will be more vulnerable to cope with the drought in the future (Figure 7.9).

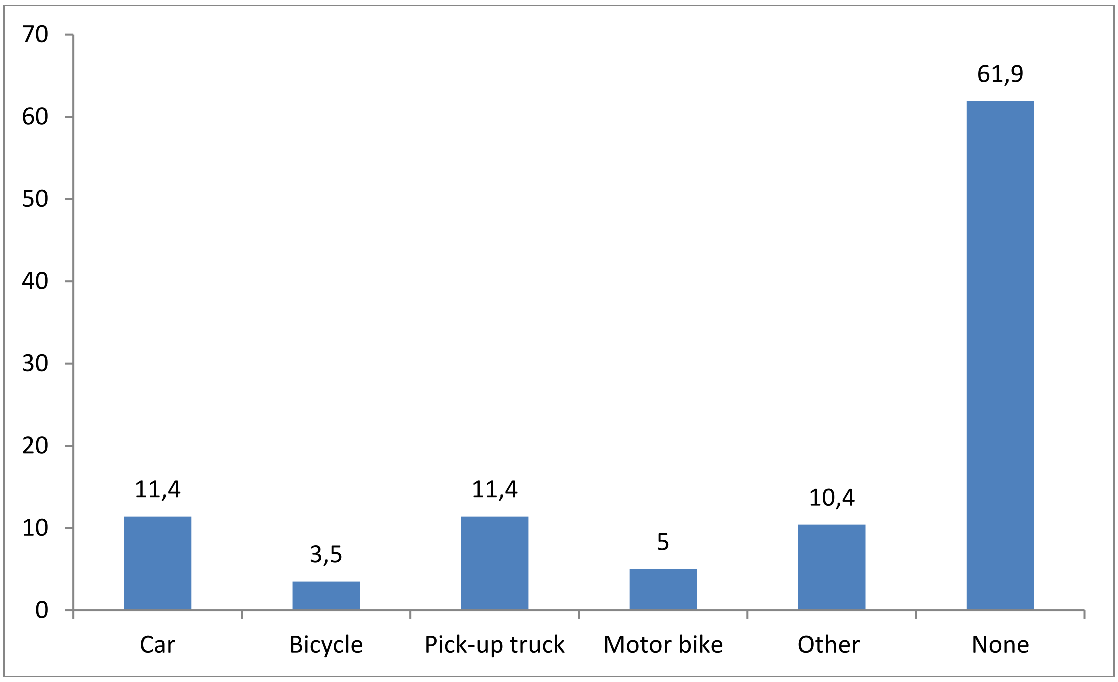


Figure 7.9: Mode of transport by smallholder farmers in the Mopani and Vhembe districts (*n* = 200)

Based on the results of the livelihood strategies analysis in the three municipalities (Greater Giyani in the Mopani district, Greater Tzaneen in the Vhembe district, and Thulamela in the Mopani district), smallholder farmers demonstrated heterogeneous livelihood strategies. Moreover, they employ different livelihood strategies based on their different possessions of natural, human, physical, social, and financial assets. According to DAFF (2012), smallholder farmers are households that rely heavily on family labour and so the farming is defined as farming that is dominated by family labour. Smallholder farmers have been supported through this effort, even though different stakeholders and development partners face difficulties streamlining their support services to the targeted groups because smallholder farming is not clearly classified.

7.3.2 Household Economy Approach

In the Limpopo Province, farmers have limited options for coping during drought because of their capital assets. Therefore, carefully selecting coping strategies for crop management that consider capacity constraints and can assist farmers in efficiently coping with droughts is essential. Smallholder farmers deploy different strategies towards resilient livelihoods, thus demonstrating significant diversification within their group. Focus group interviews and key informant interviews were conducted to identify the socioeconomic characteristics of community groups (Figure 7.10). As a result of household assets and livelihood practices, these wealth groups are defined by the community.

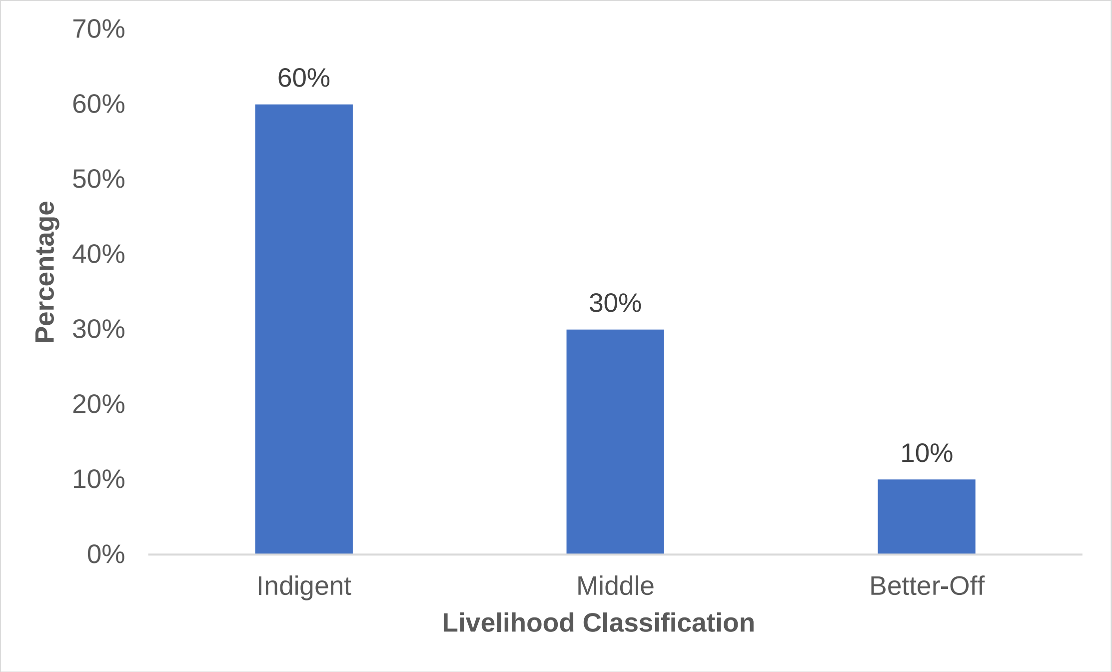


Figure 7.10: Percentage of smallholder farmers livelihood classification in the Mopani and Vhembe districts

In order to understand the activities more deeply and interdependencies between the different types of households, the wealth ranking exercise helped the assessment team stratify the rest of the assessment by socioeconomic groups. The key factors that underpin the classification of smallholder farmers in the Mopani and Vhembe districts includes salaries, level of education, social grants, production activities, household characteristics and other factors. The three groups are characterised by unreliability rainfall and annual variations in climatic and production conditions. There are three groups of smallholder farmers classified according to their livelihood's strategies in the two districts. The wealth ranking characteristics for all the three smallholder farmers are provided in Table 7.2, to facilitate comparison between them.

Table 7.2: A smallholder farmers proposed livelihood strategies for coping and adaptation to drought in the Limpopo Province

HEA BASELINE			HEA OUTCOME ANALYSIS		
Step 1:	**Step 2:**	**Step 3:**	**Step 4:**	**Step 5:**	**Step 6:**
Livelihood Classification	**Wealth Breakdown**	**Livelihood Strategies**	**The problem specification**	**Analysis of coping capacity**	**The projected outcome**
Indigent	Lack of natural assets such as land, water source and adequate rainfall. Lack access to financial capital such ass cash savings in the banks, access to credits, and convertible assets. Lack physical capital such as basic infrastructure. Human capital has been compromised by old age, level of education, and poor access to social services such as health care. Social capital such community agricultural groups to support each other within the wealth group were evidenced by the researcher.	Mainly reliant on child and old age social grants, agricultural labour, sell local crafts and some local brew. They solely depend on the farmer support programme such as production inputs and mechanization. Sustainability of livelihoods is a problem among this group.	Smallholder farmers are usually the most vulnerable to increased frequency and intensity of droughts which shorten rain season which directly affects rainfed agriculture and reduced availability of freshwater resources.	Increasing access to climate information and services. Mainstreaming weather information into agricultural extension support using bulletins to guide preparedness efforts. Plant early maturing crop varieties. Ex- and in-situ rainwater harvesting and conservation techniques. Diversification (intercropping, market gardening and indigenous fruit trees).	Smallholder farmer livelihood strategies for coping and adapting to drought by adapting to new agroecological zones and enhance crop suitability due to shortened growing duration and reducing low yields and/or crop failure. Their food security situation can be improved if well targeted with the most appropriate livelihoods and other coping and adapting strategies interventions.
Middle	Lack of physical capital to support their livelihoods aspirations and to some extent financial capital inform of cash required for	Mainly reliant on child and old age social grants, agricultural labour, sell local crafts, some local brew, and seasonal jobs	Smallholder farmers are usually the most vulnerable to increased frequency and intensity of droughts which	Access to drought early warning information before the beginning of the season (e.g. relocate livestock to higher grounds	Smallholder farmer livelihood strategies for coping and adapting to drought by promotion of seed fairs to enhance local exchange of

	investment. Fairly good access to natural capital such as construction material for sale; financial capital including convertible assets such as 2-3 small livestock at disposal; social capital mainly the government farmer support programmes.	especially during citrus season. They are eligible to benefit from farmer support programmes and to some extent human capital.	shorten rain season which directly affects rainfed agriculture and reduced availability of freshwater resources.	before an extreme events). Promote uptake of weather index-based insurance products for both crops and livestock. Use of water conservation principles e.g. 30% + mulching, rotation, and minimum tillage to conserve soil water.	seed amongst farmers and promote community-level drought tolerant seed production.
Better-off	Access to adequate productive labour, mainly through hiring and use of their own assets such as ploughs harrow, cultivator etc. They also own a lot of livestock which provides drought power. They have a good access and utilization of the five main pillars of capitals as described in DFID sustainable livelihoods framework.	Engage in relatively high profit-making income activities. Their main sources of income include sales of vegetables, livestock especially cattle, hiring out of drought power, and pension. They use irrigation as a supplementary in their fields and pumping water from the boreholes or nearby Rivers. Sustainability of livelihoods is not a major problem among this wealth group.	Smallholder farmers are usually the most vulnerable to increased frequency and intensity of droughts which shorten rain season which directly affects rainfed agriculture and reduced availability of freshwater resources.	Mainstreaming weather information into agricultural extension support using bulletins to guide preparedness efforts. Diversification of crop livestock systems to spread the risk. Promote use of standard contours in-field to facilitate appropriate infiltration and drainage; dead level contours and infiltration pits to direct run-off to recharge the water table.	Smallholder farmer livelihood strategies for coping and adapting to drought by use of farmer training on climate smart agricultural technologies that enhance coping capacities of the farmers.

Community leaders identified three main socio-economic groups through a Participatory Rural Appraisal (PRA) that applied various wealth ranking tools as presented in Table 7.2 above and other typical defining characteristics describe below:

7.3.4.1 Indigent smallholder farmer

They are typically defined by limited access to productive labour, due to their use of zero tillage tools such as hand hoes, sickles, axes and over reliance of family members to work in their fields. This group of farmers are most vulnerable and produces primarily for household consumption. A vulnerable family, a family headed by a child, a family with a disabled person, an indigent household, and a family headed by someone on welfare are included in this category. This group of farmers have at least 1-2 healthy and productive persons who can increase production in the household but are constrained by their continued dependency on government and lack of agricultural inputs such as seeds, fertilizers, and pesticides, among others.

Indigent smallholder farmers in all the three Municipalities; namely Greater Giyani, Greater Tzaneen in the Mopani District, and Thulamela in the Vhembe District of Limpopo Province cultivate in less than 1ha of land under rainfed condition. Main crops grown are the staple grains namely maize, sorghum, and other crops such as sweet potatoes, groundnuts, cassava, cowpeas, and pumpkins. Annual crop production trends for the last decade shows that indigent farmers have consistently derived less than 50% of their annual food needs from own crop production and are only able to meet up to 85% of their annual food needs exclusive of social grants. Based on their production capacity, existing evidence shows that this group of farmers can be classified as transitorily food insecure.

Sustainability of livelihoods is a problem among this group. Mainly reliant on few income sources such as child and old age social grants, agricultural labour, sell local crafts and some local brew. However, these income sources have very low profit returns and do not meet the hyper-inflation in the local market. This group of farmers lack access to three of the five main pillars of capitals as described in DFID sustainable livelihoods framework. These include total lack of access to financial capital such ass cash savings in the banks, access to credits, and convertible assets such as small livestock as a result of the annual distressful sale of their livestock over the last decade and low levels of income, severely affected by hyper-inflation. They also lack physical capital such as basic infrastructure (roads, transport, market price information). Human capital has been compromised by old age, level of education, and poor access to social services such as health care. Social capital such community agricultural groups to support each other within the wealth group were evidenced by the researcher.

7.3.4.2 Middle smallholder farmer

They are typically characterised by the ability to access relatively adequate productive labour, through various means such as hiring, and ownership of livestock used for draught power as well as other equipment such as cultivators and ox-ploughs, among others. The middle smallholder farmers produce primarily for household consumption and sell surplus production with an annual turnover of less than R50 000.

Middle smallholder farmers in all the three Municipalities; namely Greater Giyani, Greater Tzaneen in the Mopani District, and Thulamela in the Vhembe District of Limpopo Province cultivate between 1-2ha of land under rainfed condition. Main crops grown are the staple grains namely maize, sorghum, and other crops such as sweet potatoes, groundnuts, cassava, cowpeas, and pumpkins to supplement their diet. Annual crop production trends predicted to provide above 50% of their minimum annual food needs from own crop production.

Sustainability of livelihoods is a challenge among majority of the smallholder farmers in this category. Mainly reliant on few income sources such as child and old age social grants, agricultural labour, sell local crafts, some local brew, and seasonal jobs especially during citrus season. These farmers like the indigent smallholder farmers, also face some constraints in the access and utilization of the five main pillars of capitals as described in DFID sustainable livelihoods framework. They have fairly good access to natural capital such as construction material for sale; financial capital including convertible assets such as 2-3 small livestock at disposal; social capital mainly the government farmer support programmes they are eligible to benefit from and to some extent human capital. The main limitation of this group is lack of physical capital to support their livelihoods aspirations and to some extent financial capital inform of cash required for investment.

7.3.4.3 Better-off smallholder farmer

They are typically defined by their ability to access adequate productive labour, mainly through hiring and use of their own assets such as ploughs harrow, cultivator etc. They also own a lot of livestock which provides drought power. In the value chain of agriculture, forestry, and fisheries, better-off smallholder farmers produce food for household consumption and economic gain. New entrants with annual turnovers of R50001 to R1 million are usually included in this category.

Better-off smallholder farmers in all the three Municipalities; namely Greater Giyani, Greater Tzaneen in the Mopani District, and Thulamela in the Vhembe District of Limpopo Province cultivate more than 2ha of land. Main crops grown are the staple grains namely maize, sorghum, vegetables, sweet potatoes, groundnuts, cassava, cowpeas, and pumpkins to provide above 80% of their minimum annual food needs from own crop production. This smallholder farmers they use irrigation as a supplementary in their fields and pumping water from the boreholes or nearby Rivers. However, the use of borehole for irrigation is commonly in Greater Tzaneen Municipality and Rivers in the Thulamela Municipality.

Sustainability of livelihoods is not a major problem among this wealth group. However, they are affected by some of the bad economic policies in the country. The better-off smallholder farmers engage in relatively high profit-making income activities. Their main sources of income include sell of vegetables, livestock especially cattle, hiring out of drought power, and pension. They have a good access and utilization of the five main pillars of capitals as described in DFID sustainable livelihoods framework.

7.4 Conclusion

The purpose of this study was to classify the smallholder farmers according to their livelihoods in the Limpopo Province. The results demonstrate that much diversification exists inside smallholder farmers, conveying more resilient strategies towards livelihood outcomes. In terms of living standards, food consumption, asset attainment, and lower prevalence of food insecurity, those with higher education and those working for salaries have an advantage. When defining smallholder farmers and providing them with the support for development, different factors need to be taken into consideration, based on the livelihoods analysis in Mopani and Vhembe districts. Consequently, both districts do not fit the one-size-fits-all definition. In order to improve the effectiveness of smallholder farmers' interventions, smallholder farmers should be informed appropriately and have livelihoods analyses conducted whenever they are involved in an intervention. The LDARD should consider policies that will increase participation to economic accomplishments aimed at addressing the key issues that make smallholder farmers vulnerable to drought. Whatever socio-economic support is given to smallholder farmers it should be implemented in a nexus approach with climate related support to fully enhance resilience.

CHAPTER EIGHT

GENERAL DISCUSSION AND CONCLUSIONS

8.1 Introduction

The aim of this thesis was to develop an understanding of the different types of smallholder farmers, come up with appropriate livelihood strategies for coping and adaptation to drought, and to think of a lot of choices that will be based on the farmer characteristics. Even though the drought issue has been extensively researched throughout the world, this thesis made use of station observations and high-resolution climate reanalyses obtained from satellite data. Significantly, this is also the first time that an evidence-based adaptation strategy was built using the Sustainable Livelihoods Framework at the farm level to protect and improve smallholder farmers' livelihoods. In addition, the study provides a unique and new contribution to understanding livelihood strategies that appropriate support can be provided to keep the farmers in production during drought. This chapter provides a summary and synthesis of the key findings of this thesis mainly from Chapters 4 to 7, and how they contribute to the body of knowledge. Some adaptive strategies for drought management are offered with a focus on water supply problems and water use efficiency in rural communities. Research questions and insights that arise from this thesis are recommended for future studies. In conclusion, this section proffers some opportunities and coping strategies for smallholder farmers to 'live with drought' in Limpopo Province, South Africa.

8.2 Findings and conclusions

As climate variability increases and the impacts of climate change become more acute, it is critical for policy-makers to take an honest look at the Land Restitution Program to include preparedness and building adaptive capacity to climate change impacts such as drought and flooding. Many of the skills that are needed are not traditional technical skills, but rather how to foster stronger partnerships, adaptive management, and the ability to facilitate learning. Government systems are often not well equipped to be flexible and collaborative, so changes are needed. The goal is for resource-poor and vulnerable smallholder farmers of the Limpopo Province to adapt and cope with the harsh realities of recurrent drought in a changing climate. The soil water regime of both districts regarding crop production is evidenced by the CMI values, which indicate that the area is becoming soil moisture scarce. The analysis also shows that both districts are climate change hot spot areas, highly vulnerable to the impacts of climate change. The analysis data from 1960 to 2018 demonstrated an increased recurrence of drought, as with rainfall variability, which leads to water scarcity and food insecurity. Major climate change impacts in the districts under study are being felt through water resources, thereby affecting all sectors.

In the past, poor planning and management have made the effects of drought worse. Farm management is likely to be focused on limiting risk if the pattern of precipitation from the time of planting is unclear, which frequently entails choosing modest inputs and low but stable yields. Drought prediction may need to be integrated into an early warning system. It is crucial to share scientific knowledge with decision-makers and isolated rural communities for decision support systems. It is crucial to let users of weather and climate information about the limitations of climate research and the main uncertainties. Operational staff in meteorology, hydrology and agronomy also need to remain up to date with advances in drought research. Drought may have negative and far-reaching consequences on society, including human health. As shown in Chapter 4, droughts are often accompanied by high land surface and air temperatures or heat waves which may cause a decrease in the Crop Moisture Index (CMI) and make smallholder farmers more vulnerable. Advances in remote sensing of the environment have contributed to improved drought monitoring over southern Africa. Satellite observations of rainfall, soil moisture, and vegetation are available for early warning. National Meteorological Services of the region need to invest in the deployment of real-time automatic weather observing systems to improve monitoring and predictability.

Resources should now be channelled towards adaptation and building resilient communities. One systematic, transformative, and integrated approach that is being spearheaded to guide policy and decision-making to develop informed adaptation strategies is the Water-Energy-Food (WEF) nexus, a polycentric approach that considers all resources in equal terms and is a decision support tool to mitigate trade-offs and maximize on synergies. Unlike the integrated water resources management (IWRM) which is water-centric, the WEF nexus is multi-centric, promoting cross-sectoral resource management. Sectoral approaches in resource management only transfer challenges to other sectors as each sector pursues its strategies and policies. However, the WEF nexus stimulates stakeholder engagement before the implementation of any developmental project. Rainfall amounts and timing are moving due to climate change, which has an impact on the management of water resources. A more adaptable approach to managing water in line with how the climate is changing can result from better monitoring of historical climatic variability and current trends. Nevertheless, it can be challenging to include long-term scenarios in planning for future water resources due to the uncertainties surrounding climate change scenarios. In this context, assistance with the creation of training and/or instruction materials on how to incorporate climate change scenarios into decision-making would be beneficial.

Drought resilience strategies are usually reactive and increase the use of existing resources, which may impede their benefit/relief to those they are supposed to help. In order to reduce the impact of climate change on smallholder farmers, different adaptation strategies have been adopted. Small businesses, casual employment, irrigation, planting drought-resistant crops, planting early maturing maize varieties, and changing planting dates are all adaptation strategies. Institutions working with smallholder farmers must coordinate well to address challenges associated with climate change adaptation. Education of young farmers is crucial to implementing important alternative technologies; drought warnings are one of the major barriers to non-adoption. Adaptive leadership and capacity building must be strengthened by national and provincial governments to deal with the drought better.

Table 8.1: Context-based adaptation strategies in the Limpopo Province

Climate Change Impact	**Recommended Adaptation Strategy**
Shortened rain season (Starting around December and ending in March)	• Provide access to agro-meteorological information and services • Mainstreaming weather information into agricultural extension support using social media • Plant early maturing under-utilized crop varieties that adapt to local hash conditions • Crop diversification and intercropping • Ex- and in-situ rainwater harvesting and conservation techniques
Intra-seasonal dry spells during the cropping season	• Adopt a crop diversification system • Construct small water reservoirs in support of ex- and in-situ rainwater harvesting • Adopt water conservation technologies (mulching, ridging, etc.) and employ limited tillage to conserve soil water
Increasing temperatures and heatwaves	• Breed heat-tolerant livestock and encourage destocking during drought periods • De-bushing for rangeland rehabilitation • Invest in smallholder fodder production and distribute drought-resistant seeds • Provide additional feeding for cattle • Encourage the rearing of small stock production • Promote the cultivation of underutilised and small grains, e.g., sorghum and millets • Promote mulching to conserve to reduce erosion and lower soil temperature • Promote and encourage intercropping
Increased frequency and intensity of droughts	• Access to early warning services throughout the year and especially during the cropping season • Crop diversification through intercropping, market gardening, etc. • Promote modern technologies like weather-based index-insurance • Stone bunds & terracing for runoff mitigation

	• Adopt modern water conservation practices (e.g., 30%+ mulching, crop, etc.) • Adopt contour planting to enhance infiltration and drainage
Intra and inter-seasonal rainfall variability	• Use of climate-smart agriculture methods • Use social media to reach smallholder farmers with climate information and services • Diversify crop and livestock systems to reduce risk and vulnerability
Increased risk of flooding (flash floods/cyclones) from January to March	• Enhance access to weather information in near real-time • Mainstreaming weather forecasts into extension services • Enhance disease surveillance through modern technologies and predict pests and diseases • Agro-forestry for increased water capture • Stone bunds and terracing for runoff mitigation

When defining smallholder farmers and providing them with development support, several factors need to be taken into account, based on results of the livelihoods analysis in Limpopo Province. Whenever smallholder farmers are involved in interventions, a livelihoods analysis is a good way to inform them properly and help them be more effective. There are three groups of smallholder farmers classified according to their livelihood strategies in the Limpopo Province. The key factors that underpin the classification of smallholder farmers in the Limpopo Province include salaries, level of education, social grants, production activities, household characteristics and other factors. The three groups are characterised by unreliability rainfall and annual variations in climatic and production conditions. The three groups were classified as indigent, middle, and better-off smallholder farmers.

The indigent smallholder farmers are typically defined by limited access to productive labour, due to their use of zero tillage tools such as hand hoes, sickles, axes and over reliance of family members to work in their fields. This group of farmers are most vulnerable and produces primarily for household consumption. This category includes vulnerable women and youth, child-headed households, persons with disabilities, farm workers, and households that are registered as indigents. This group of farmers lacks agricultural inputs such as seeds, fertilizers, and pesticides, among others. Sustainability of livelihoods is a problem among this group. Mainly reliant on few income sources such as child and old age social grants, agricultural labour, selling local crafts, and some local brew. This group of farmers lacks access to three of the five main pillars of capital as described in DFID sustainable livelihoods framework. These include a total lack of access to financial capital such as cash savings in the banks, access to credits, and convertible assets such as small livestock as a result of the annual distressful sale of their livestock over the last decade and low levels of income, severely affected by hyper-inflation. They also lack physical capital such as basic infrastructure. Human capital has been compromised by old age, level of education, and poor access to social services such as health care.

Middle smallholder farmers are typically characterised by the ability to access relatively adequate productive labour, through various means such as hiring, and ownership of livestock used for draught power as well as other equipment such as cultivators and ox-ploughs, among others. The middle smallholder farmers produce primarily for household consumption and may market limited surplus production with an annual turnover of less than R50 000. The sustainability of livelihoods is a challenge among the majority of the smallholder farmers in this category. Mainly reliant on few income sources such as child and old age social grants, agricultural labour, selling local crafts, some local brew, and seasonal jobs, especially during citrus season. These farmers like the indigent smallholder farmers, also face some constraints in the access and utilization of the five main pillars of capitals as described in DFID sustainable livelihoods framework. They have fairly good access to natural capital such as construction material for sale; financial capital including convertible assets such as 2-3 small livestock at disposal; social capital mainly the government farmer support programmes they are eligible to benefit from and to some extent human capital. The main limitation of this group is the lack of physical capital to support their livelihoods aspirations and to some extent financial capital inform of cash required for investment.

Better-off smallholder farmers are typically defined by their ability to access adequate productive labour, mainly through hiring and use of their own assets such as ploughs harrow, cultivator, etc. They also own a lot of livestock which provides drought power. Agricultural, forestry, and fisheries activities along the value chain provide income for better-off smallholder farmers who produce for household consumption. A new entrant usually has a revenue range between R50 000 and R1 million per year. The sustainability of livelihoods is not a major problem among this wealth group. However, they are affected by some of the bad economic policies in the country. The better-off smallholder farmers engage in relatively high profit-making income activities. Their main sources of income include sell of vegetables, and livestock especially cattle, hiring out of drought power, and pension. They have good access and utilization of the five main pillars of capitals as described in DFID sustainable livelihoods framework.

Table 8.2: A smallholder farmers proposed livelihood strategies for coping and adaptation to drought in the Limpopo Province

HEA BASELINE			HEA OUTCOME ANALYSIS		
Step 1:	**Step 2:**	**Step 3:**	**Step 4:**	**Step 5:**	**Step 6:**
Livelihood Classification	**Wealth Breakdown**	**Livelihood Strategies**	**The problem specification**	**Analysis of coping capacity**	**The projected outcome**
Indigent	Lack of natural assets such as land, water source and adequate rainfall. Lack access to financial capital such ass cash savings in the banks, access to credits, and convertible assets. Lack physical capital such as basic infrastructure. Human capital has been compromised by old age, level of education, and poor access to social services such as health care. Social capital such community agricultural groups to support each other within the wealth group were evidenced by the researcher.	Mainly reliant on child and old age social grants, agricultural labor, sell local crafts and some local brew. They solely depend on the farmer support programme such as production inputs and mechanization. Sustainability of livelihoods is a problem among this group.	Smallholder farmers are usually the most vulnerable to increased frequency and intensity of droughts which shorten rain season which directly affects rainfed agriculture and reduced availability of freshwater resources.	Increasing access to climate information and services. Mainstreaming weather information into agricultural extension support using bulletins to guide preparedness efforts. Plant early maturing crop varieties. Ex- and in-situ rainwater harvesting and conservation techniques. Diversification (intercropping, market gardening and indigenous fruit trees).	Smallholder farmer livelihood strategies for coping and adapting to drought by adapting to new agroecological zones and enhance crop suitability due to shortened growing duration and reducing low yields and/or crop failure. Their food security situation can be improved if well targeted with the most appropriate livelihoods and other coping and adapting strategies interventions.
Middle	Lack of physical capital to support their livelihoods aspirations and to some extent financial capital inform of cash required for investment. Fairly good access to	Mainly reliant on child and old age social grants, agricultural labor, sell local crafts, some local brew, and seasonal jobs especially	Smallholder farmers are usually the most vulnerable to increased frequency and intensity of droughts which shorten	Access to drought early warning information before the beginning of the season (e.g. relocate livestock to higher grounds before an extreme	Smallholder farmer livelihood strategies for coping and adapting to drought by promotion of seed fairs to enhance local exchange of seed amongst farmers and

	natural capital such as construction material for sale; financial capital including convertible assets such as 2-3 small livestock at disposal; social capital mainly the government farmer support programmes.	during citrus season. They are eligible to benefit from farmer support programmes and to some extent human capital.	rain season which directly affects rainfed agriculture and reduced availability of freshwater resources.	events). Promote uptake of weather index-based insurance products for both crops and livestock. Use of water conservation principles e.g., 30% + mulching, rotation, and minimum tillage to conserve soil water.	promote community-level drought tolerant seed production.
Better-off	Access to adequate productive labor, mainly through hiring and use of their own assets such as ploughs harrow, cultivator etc. They also own a lot of livestock which provides drought power. They have a good access and utilization of the five main pillars of capitals as described in DFID sustainable livelihoods framework.	Engage in relatively high profit-making income activities. Their main sources of income include sales of vegetables, livestock especially cattle, hiring out of drought power, and pension. They use irrigation as a supplementary in their fields and pumping water from the boreholes or nearby Rivers. Sustainability of livelihoods is not a major problem among this wealth group.	Smallholder farmers are usually the most vulnerable to increased frequency and intensity of droughts which shorten rain season which directly affects rainfed agriculture and reduced availability of freshwater resources.	Mainstreaming weather information into agricultural extension support using bulletins to guide preparedness efforts. Diversification of crop livestock systems to spread the risk. Promote use of standard contours in-field to facilitate appropriate infiltration and drainage; dead level contours and infiltration pits to direct run-off to recharge the water table.	Smallholder farmer livelihood strategies for coping and adapting to drought by use of farmer training on climate smart agricultural technologies that enhance coping capacities of the farmers.

Smallholder farmers are often negatively affected by climate change, which is why extension officers and other stakeholders in the agricultural sector should continue to empower them as much as possible in order to mitigate its impacts. Access to extension services can improve farmers' perception of and ability to adopt agricultural innovations, including climate change adaptations. The protection of pastures and livestock is therefore necessary as a proactive measure. Increasing awareness of climate change has prompted communities to find more effective ways to build resilient communities with their limited resources. Capacity building, technological demonstrations, and information dissemination are all elements that are necessary for science and policy interfaces to work effectively.

As part of the study, rainwater harvesting is recommended to conserve water during droughts and alternative irrigation methods are recommended to conserve water during the growing season. Water harvesting technologies have been around for millennia, and new ones are constantly being developed. Micro-catchment technologies capture runoff near growing crops and replenish soil moisture, as well as macro-catchment technologies that handle large runoff flows diverted from surfaces like roads, hillsides, and pastures. Several countries have relied on rainwater harvesting to improve water availability and agricultural output, alleviating poverty, reducing water waste, restoring groundwater, empowering women to manage water and other natural resources, and reducing floods and droughts by storing excess water.

Smallholder farmer livelihoods, the economy, the environment, and politics are all adversely affected by drought. It takes a lot of effort, money, and research to improve adaptive capacity and increase the capacity to properly plan for these risks. Depending on the situation, it may be beneficial to build capacity internally in some cases or through intergovernmental, international, or external experts. It is evident that many of the earlier themes such as enhancing leadership and partnerships, enhancing data repositories, and better comprehension of the social-ecological system contribute to the development of adaptive capacity. However, some technical specialists had trouble persuading politicians to agree with them, and some politicians had trouble comprehending the technical difficulties. For drought-related actions to consider smallholder farmers' coping and adaptation techniques as well as technical, resource, and institutional imperatives and limits, it is critical to increasing engagement and understanding between the two groups.

8.3 Future research

This study has focused on historical drought in a summer rainfall region of the Limpopo Province for the satellite era from 1960 to 2018. Future research must focus on the following:

- Most of southern Africa's semi-arid rangelands are unsuitable for farming and are instead used for grazing cattle herds and as wildlife refuges. The size and health of the livestock herds in these areas determine the wealth and means of subsistence of rural people. It is important to investigate how drought has affected rural livelihoods and animal herds (including goats and cattle).
- Most of the research under consideration are rural-based, and they do not analyse how drought affects smallholder farmers along the rural-to-urban gradient. Few studies have been done on how droughts affect smallholder farmers' ability to raise livestock in urban areas, making it difficult for city officials to better understand and prepare for droughts in the future.
- The lack of research on the effects of drought on smallholder farmers in urban settings demonstrates how little is known about South Africa's drought gradient from rural to urban. Urban areas are more susceptible to drought because of the growth in the urban population and the increased use of resources, such as water, which emphasizes the urgent need for research on the effects and reactions of drought in urban areas.
- All levels of government need to do more in order to include climate change in local disaster management plans. It's critical to investigate ways to incorporate meteorological data at the local levels because municipalities have not traditionally planned their own water resources.
- The ability to accurately reflect reality is reduced when information and effort put into analysing risk and exposure at the lowest resolution are aggregated at administrative boundary levels, so future assessments may benefit from new methods to assess vulnerability beyond administrative boundaries (for example, pixel-level vulnerability data).
- Creating a trustworthy and uniform database of losses and damages pertaining to agricultural systems in South Africa could improve this evaluation in addition to looking at the environmental, social, and political factors determining drought risk. Additionally, loss data collections can be helpful for seeing patterns and trends in data over time as well as for achieving coordinated and consistent application of risk reduction techniques.

- On the predicted effects of global warming on drought features and drought trends, there is some debate. Decisions about adaptation are impacted by uncertainties in climate model physics and model forecasts depending on low- or high-mitigating scenarios. As a result, the issue of climate change is still unclear and needs to be researched.
- The conterminous United States has been the subject of most of the research conducted globally on drought and drought monitoring utilizing indices. Such initiatives might concentrate on southern Africa, where the impacts of drought on populations and businesses can be severe and where rainfall is unpredictable.

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APPENDIX A: LIMPOPO DEPARTMENT OF AGRICULTURE AND RURAL DEVELOPMENT CONSENT LETTER

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
AGRICULTURE AND RURAL DEVELOPMENT

Ref: 12R

Enquiries: **Dr S. B. Dikgwatlhe**
0152943229
0608338574

24 November, 2017

MR. SHIKWAMBANA SYDNEY (217301592, PhD Candidate)
Faculty of Applied Sciences
Department of Environmental and Occupational Studies
Cape Peninsula University of Technology (CPUT)
South Africa

RE: SMALLHOLDER FARMER LIVELIHOOD STRATEGIES FOR COPING AND ADAPTING TO DROUGHT IN THE LIMPOPO PROVINCE, SOUTH AFRICA.

1. Your letter of request for permission to conduct research has reference.

2. Kindly take note that your request to conduct Research in Limpopo Province has been recommended and approved, this after a thorough presentation by your team on the mother project titled: *Improving smallholder farmer livelihoods through developing strategies to cope and adapt during drought periods in South Africa*. You will be required to present your proposal to the LDARD Departmental Research Forum/Committee as an when required, failure to do so will result in the retraction of the recommendation and the approval thereof. You are kindly required to visit the ***Office of the Directors*** in Mopani and Vhembe districts where the study will be conducted before you start with the actual work, this in order to brief them on the study and your request, this is also important in raising awareness particularly with Municipality Managers (Local Agricultural Office). The Department is prepared to embark on any activity to make this research work possible, which could assist our communities in ultimate improvement of livelihoods at large particularly relating to climatic issues which has become a major challenge in recent years.

3. Kindly take note that you will be expected to hand over a copy of your final report to the Department for record purposes as well as for reporting. You may also be invited to share your findings in various Departmental Research Forums at Head Office or District level.

4. Hoping that you will find this in order
Kind regards

Dr. SB Dikgwatlhe (Pr. Sci. Nat.)
PhD (*CAU*), MSc (*UFS*), BSc Hons, BSc (*UNW*)
Acting Director-Research Services

24 November, 2017
Date

67/69 Biccard Street, POLOKWANE, 0700, Private Bag X9487, Polokwane, 0700
Tel: (015) 294 3229 Fax: (015) 294 4512 Website: http://www.lda.gov.za
The heartland of Southern Africa - development is about people!

APPENDIX B: ETHICAL CLEARANCE

Cape Peninsula University of Technology

P.O. Box 1906 • Bellville 7535 South Africa •Tel: +27 21 953 8677 (Bellville), +27 21 460 4213 (Cape Town)

Ethical clearance certificate **Reference no:** 217301592

Office of the Chairperson Research Ethics Committee	**Faculty of Applied Sciences**

The Faculty Research Committee, in consultation with the Chair of the Faculty Ethics Committee, hereby approves ethical clearance for research proposal of **SYDNEY SHIKWAMBANA (217301592)** for research activities related to a project undertaken for a **PHD IN ENVIRONMENTAL HEALTH** at the Cape Peninsula University of Technology.

Supervisor(s): DR BONGANI NCUBE

Title of dissertation/ thesis:	Smallholder farmer livelihood strategies for coping and adapting to drought in the Limpopo Province, South Africa

As such, this ethical clearance is issued on the basis that due diligence will be taken when involving human/animal subjects. Ethical clearance given was on the basis that, all the required/requested information complied with minimum standards for ethical clearance.

Comments (Add any further comments deemed necessary, eg permission required)

1. Ethical clearance is granted for the duration of the study. An annual progress report is required.
2. Research activities are restricted to those detailed in the research proposal.
3. Data/Sample collection/Participant consent permission required for this study and the study must ensure that the questionaires are available in the three regional languages, and/or an interpreter must be made available. Questions are therefore restricted to those submitted for evaluation. Any changes will then require the submission of a new ethical clearance application.
4. The research team must comply with conditions outlined in AppSci/FREC/2015/1.1 v1, CODE OF ETHICS, ETHICAL VALUES AND GUIDELINES FOR RESEARCHERS.

[signature]	26/04/2018
Signed: Chairperson: Research Ethics Committee	**Date**

Cape Peninsula University of Technology

Data/Sample collection permission is required for this study.

Surname & name	SYDNEY SHIKWAMBANA
Student Number	217301592
Degree	PHD IN ENVIRONMENTAL HEALTH
Title	Smallholder farmer livelihood strategies for coping and adapting to drought in the Limpopo Province, South Africa
Supervisors	DR BONGANI NCUBE
FRC Signature	[signature]
Date	26/04/2018

Cape Peninsula
University of Technology

P.O. Box 1906 Bellville 7535 South Africa ,Tel: +27 21 953 8677 (Bellville), +27 21 460 4213 (Cape Town)

Office of the Chairperson Research Ethics Committee	Faculty of Applied Sciences

The Faculty Research Committee, in consultation with the Chair of the Faculty Ethics Committee, have determined that the research proposal of SYDNEY SHIKWAMBANA for research activities related to the: PHD IN ENVIRONMENTAL HEALTH at the cape Peninsula University of Technology does require / does not require ethical clearance.

Proposed title of dissertation/ thesis:	Smallholder farmer livelihood strategies for coping and adapting to drought in the Limpopo Province, South Africa

Comments (Add any further comments deemed necessary, eg permission required) Research activities are restricted to those detailed in the research proposal. The research requires ethical clearance due to the questionnaires to be administered.

Signed: Chairperson: Research Ethics Committee	26/04/2018

APPENDIX C: QUESTIONNAIRE

Cape Peninsula
University of Technology

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF ENVIRONMENTAL AND OCCUPATIONAL HEALTH

Smallholder farmer livelihood strategies for coping and adapting to drought in the Limpopo Province, South Africa

Objective: ***To analyse the livelihoods coping and adapting strategies of smallholder farmers during drought***

INTRODUCTION

Smallholder farmers in the Limpopo Province are not homogenous; hence the criteria for characterising them are unclear. Drought poses serious threats to smallholder farmer livelihood strategies, and eventually their livelihood outcomes. Due to their heterogeneous nature, their coping and adapting strategies to drought is complex, and they adopt diverse strategies in order to achieve, improve or sustain their livelihood outcomes during drought. The purpose of this questionnaire is to analyse the smallholder farmers' livelihoods coping and adapting strategies to drought. This questionnaire is aimed at collecting data on the livelihoods assets possessed by the smallholder farmers, their livelihood strategies and to identify the organisations working with them in the Mopani and Vhembe districts.

IDENTIFICATION DETAILS	
QUESTIONNAIRE NO.	
RESPONDENT NAME	
DISTRICT NAME	
TOWN NAME	
FARM NAME/NO.	
DATE OF INTERVIEW	
START TIME	
END TIME	
INTERVIEWER	

SECTION A: GENERAL INFORMATION

A1 Please tell me a brief background of yourself? ---

A2 Do you consider yourself as a farmer?

a. Yes	1
b. No	2
c. I don't know	3

A3 Do you consider yourself as a smallholder farmer?

a. Yes	1
b. No	2
c. Not sure	3

A4 Please explain your answer? ---

A5 Do you consider your farming as a business?

a. Yes	1
b. No	2
c. Not sure	3

A6 When did you start farming?--

A7 What kind of farming enterprises do you practice? (Select all options that apply)

a. Grain Production (Specify)	1
b. Cattle Production (dairy/beef)	2
c. Sheep Production (wool, lamb/mutton)	3
d. Pig Production	4
e. Vegetable Production (Specify)	5
f. Other (please specify)	

SECTION B: ASSETS

B1. Human assets (Education and Skills)

B1.1 Which age group do you belong to? (Specify)

a. 18-25	1
b. 26-35	2
c. 36-45	3
d. 46-55	4
e. 56-65	5
f. 66-75	6
g. 75 or older (Please specify)	

B1.2 Gender of the household head (Please tick the applicable box)

a. Male	1
b. Female	2

B1.3 What is the size of your family? (Specify)

a. 2-4	1
b. 5-7	2
c. 7-10	3
d. 10 or more	4

B1.4 How many family members are involved in the farming business? (Specify)

a. 1-2	1
b. 3-5	2
c. 5 or more	3

B1.5 Do you sometimes hire casual labour?

a. Yes	1
b. No	2

B1.6 If yes how many? (Specify) --

B1.7 How often do you hire casual workers?

a. Once a month	1
b. Once a year	2
c. Weekly	3
d. Other (Specify)	4

B1.8 Do you have permanent workers?

a. Yes 1

b. No 2

B1.9 If yes, how many permanent workers do you have? -------------------------------

B1.10 What is your highest level of education? (Specify)

a. Never been to school 1

b. Grade R to grade 8 2

c. Grade 9 to grade 12 3

d. Matriculated 4

e. National certificate 5

f. Tertiary qualification 6

B1.11 Do you have any farm-related training?

a. Yes 1

b. No 2

B1.12 If yes, what farm related training do you possess? -------------------------------------
----

B1.13 Which of the following events have you ever attended?

a. Farmers' days 1

b. Information sessions 2

c. Demonstration sessions 3

d. Training 4

e. Workshops 5

f. Other (Please specify)

B1.14 Do you need any skills development training?

a. Yes 1

b. No 2

c. Maybe 3

B1.15 If yes, what skills training do you need? ---

B2. Financial Capital

B2.1 Are you employed?

a. Yes	1
b. No	2

B2.2 If yes, what type of employment is it?

a. Self-employment	1
b. Part-time	2
c. Full-time	3
d. Other (Specify)	

B2.3 Please tick the different sources of income that apply to you?

a. Pension	1
b. Farming	2
c. Social grant	3
d. Remittances	4
e. Other (Specify)	

B2.4 If remittances are one of the sources of income, where do they come from?

a. Son	1
b. Daughter	2
c. Mother	3
d. Father	4
e. Other (Specify)	

B2.5 Do you have access to any credit providers?

a. Yes	1
b. No	2

B2.6 If yes to the above question, mention the organisations that provide credit to you?

a. Co-operatives	1
b. Commercial Bank	2
c. Land Bank	3

d. Other (Please specify)

B2.7 What are the conditions of the credits that you get from your providers?

a. Interest rates 1
b. Contract farming 2
c. Collateral 3
d. Other

B2.8 Please indicate the different ways in which you save money?

a. Livestock 1
b. Cash at hand 2
c. Bank savings 3
d. Other (Please specify)

B3. Natural capital (land; water etc.)

B3.1 How many hectares of land do you have? (Specify)

a. Less than 1ha	1
b. 1 to 1.9ha	2
d. 2 to 2.9ha	3
e. 3 to 3.9ha	4
f. Above 4ha	5

B3.2 How much of your total land do you cultivate? (Specify) -------------------------------
----

B3.3 How did you obtain the land?

a. Government leased	1
b. Municipality-leased	2
c. Inherited	
d. Rented	3
e. Purchased	4
f. Other (specify)	

B3.4 Is your land enough for use?

a. Yes 1
b. No 2

B3.5 If no, have you tried to secure more land?

a. Yes	1
b. No	2

B3.6 If yes, from where have you tried to secure it? --

B3.7 Where do you obtain water for agricultural use?

a. Well	1
b. Borehole	2
c. Dam	3
d. Tap	4
e. River	5
f. Other (Specify)	

B3.8 What type of authorisation do use to access water from the source(s) you indicated above?

a. Through municipality	1
b. Through general authorisation	2
c. Through water rights	3
d. Other (Please specify)	

B3.9 What type of infrastructure do you use to transport water from the source?------
----

B4. Physical capital (Transport; Shelter)

B4.1 What mode of transport do you own?

a. Car	1
b. Bicycle	2
c. Pick-up truck/Bakkie	3
d. Lorry	4

e. Motor bike 5

f. Other (Specify)

B4.2 Is there any public transport to take your produce to the markets?

a. Yes 1

b. No 2

B4.3 Where are your markets for the produce? --

B4.4 How far is your markets for the produce? ---

B4.5 How much do you pay to transport your produce to the market? ----------------------
----

B4.6 How do you market your produce? ---

B4.7 Do you own a house?

a. Yes 1

b. No 2

B4.8 What other buildings in addition to your house do you own?

a. Yes 1

b. No 2

B4.9 If yes to the above, please mention them?

a. Storage facility 1

b. Labour houses 2

c. Animal housing 3

d. Other (Please specify)

B4.10 What form of energy do you use for agricultural and domestic purposes?

a. Solar 1
b. Electricity 2
c. Gas 3
d. Wood 4
e. Other (Specify)

B4.11 What mode of communication do you use?
a. Cell phone 1
b. Home phone 2
c. Email 3
d. Postal 4
e. Other (Specify)

B4.12 Are the modes of communication available in your area relevant to your needs?
a. Yes 1
b. No 2

B5 Social assets (connections, networks, formal groups)

B5.1 Do you belong to any farming group in your community?
a. Yes 1
b. No 2

B5.2 Do you pay membership fees to the group?
a. Yes 1
b. No 2

B5.3 How often do you meet as a group?
a. Once a week 1
b. Once a month 2
c. Once a year 3
d. Other (Please specify) 4

B5.4 What activities take place in your meetings? ---

B5.5 Do you attend the meetings in your group?

a. Yes	1
b. No	2

B5.6 How often do you attend the meetings in your group

a. Always
b. Most of the times
c. Rarely
d. Not al all

B5.7 Is your membership in the group helpful?

a. Yes	1
b. No	2
c. Maybe	3

B5.8 According to your view, is your group functioning well?

a. Yes	1
b. No	2
c. Maybe	3

SECTION C: VULNERABILITY COMPLEX (DROUGHT)

C1 According to your understanding, what is drought? --

C2 How many droughts can you still remember that took place since you started farming? --
----

C3 In which year(s) did the droughts you mentioned occur?

C4 How has the current drought affected you?--

SECTION D: LIVELIHOOD COPING AND ADAPTING STRATEGIES DURING NORMAL AND DROUGHT PERIODS

D1. ***Strategies in general***

D1.1 Please explain the different ways in which you make a living when there no drought?--
----

D2. Coping strategies during drought

D2.1 Please explain how you have managed to survive the current drought?-------------
----

D3. Adapting strategies during drought

D3.1 Did you plan for drought before it came?

a. Yes 1

b. No 2

D3.2 How did you plan? --

D3.3 If no, what prevented you from putting in place any plans? ----------------------------
----

E. ORGANISATIONS AND PROCESSES

E1. Government, policies and institutions

E1.1 In the most recent drought, which organisations supported you? ---------------------
----

E1.2 How did they support you? --

General question

What challenges do you experience in your farming?----------------------------------

----

RESPONDENT'S CLOSING REMARKS

THANK YOU FOR YOUR TIME!!!