

Dynamism of rural mountain livelihoods under a changing climate:  
The case of the Eastern Free State Region of South Africa

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## DECLARATION 1

I declare that this thesis, submitted in fulfilment of the Doctor of Philosophy degree in Environmental Geography at the University of the Free State, is my independent work, which has not been submitted in any form to another university or faculty. I furthermore cede copyright of the thesis in favour of the University of the Free State. All the work of others has been acknowledged by means of references.

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## DECLARATION 2: PUBLICATIONS

The co-author of the manuscript publications directed and supervised the research that forms the basis for the thesis. My role in each of the papers and presentations is indicated at the end of this declaration. The \* after the author's name indicates the corresponding author for each publication.

### Chapter 2

1. Msimanga, L.\*, & Mukwada, G. (2022). Themes in climate change and variability within the context of rural livelihoods: A systematic literature review. *Research in Globalization*, p:100101. <https://doi.org/10.1016/j.resglo.2022.100101>

### Chapter 3

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Work still under review

### Chapter 4

3. Msimanga, L.\*, & Mukwada, G. (2022). An assessment of the perceptions of local communities in the Eastern Free State Region of South Africa regarding the impacts of climate change on livelihoods. *Transactions of the Royal Society of South Africa*

Work still under review

### Chapter 5

4. Msimanga, L.\*, & Mukwada, G. (2022). An evaluation of the effectiveness of the adaptation strategies in addressing the impacts of climate change on livelihoods in the Eastern Free State Region, South Africa. *Cogent Social Sciences*

My roles were data collection, data extraction, analysis and writing up the papers.

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Signed: Lokuthula Msimanga

Date: \_\_\_\_\_

## **DEDICATIONS**

This thesis is dedicated to my uncle, Mr Z. Msimanga.

## **ABSTRACT**

The research was conducted in the Thabo Mofutsanyane District of the Eastern Free State Region of South Africa. This region's complicated climate and topography have an impact on the environment and socioeconomic aspects of the local population. Consequently, climate change poses a significant threat to local mountain communities, directly affecting their livelihoods. As a result, local communities have developed adaptation strategies to safeguard their livelihoods. However, the success of these adaptation strategies has not been adequately analyzed in relation to climate change impacts in this region. For this reason, the study aimed at determining the most preferred adaptation strategies implemented by the local communities in Thabo Mofutsanyane District, and the extent to which these strategies could be considered effective in building resilient mountain communities.

Gridded monthly maximum and minimum temperature, and average rainfall data from 1960 to 2019 were extracted from Climate Explorer. The Mann Kendall Test and Sen's slope estimate were employed to identify the nature and magnitude of the trends and their significance. The Standardized Precipitation Index (SPI) was calculated for the January to March (JFM) and October to December (OND) subseasons and for the ONDJFM in R-Studio 1.1.1717 software. A questionnaire survey was carried out to determine the perceptions of local communities about climate trends and the impacts of climate change on rural livelihoods in the region. The Statistical Package for the Social Sciences and Microsoft Excel 2016 were used to analyse the data.

The results indicate a significant rise in the long-term yearly mean minimum and maximum temperatures by  $0.034^{\circ}\text{C}/\text{annum}$  and  $0.011^{\circ}\text{C}/\text{annum}$ , respectively. SPI data show severe droughts occurred during the JFM sub-season in 1973 (-1.21), 1983 (-1.755), 1992 (-1.55), and 2016 (-1.10). Extreme droughts occurred in 1990 (SPI= -1.91) during the JFM sub-season. The most severe droughts (SPI < -1.645) in the OND seasons were recorded in 1994, 1990 and 2019. The respondents reported that their lives and livelihoods have shifted due to changes in climate, leading to implications for the agricultural and socio-economic systems. The adverse environmental impacts induced by climate change reported by the communities include declining water quality and quantity (67 %), crop loss (48 %), reduced crop yields (33 %), animal diseases (38 %), and livestock mortality (68 %). Households also cited climate-related socio-economic impacts, such as higher prices, loss of farm and non-farm income, and increased labour as adverse effects of climate change. Local households adopted different livelihood strategies, including new water and soil management tactics, purchasing of livestock

feeds, adoption of drought resistant livestock species, and socio-economic measures. Respondents determined the effectiveness of adaptation measures based on observations of improved crop production and yields because of implementing soil management tactics and use of drought/frost resistant seed varieties; improved livestock health as a result of providing livestock with water and purchasing supplementary feeds; and improved health as a result of proper water management strategies. The research concludes that determining the context-specific adaptation techniques that these communities can apply will depend on the mountain communities' perceptions of climate change impacts on their livelihoods. Therefore, combining scientific knowledge with data on community perceptions and local knowledge about climate change could enhance effectiveness of climate change adaptation strategies. The study recommends evaluating the adaptation strategies local communities have implemented over time and suggesting alternative coping mechanisms that could be implemented in the region.

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## **LIST OF ACRONYMS**

DfID	-	Department of International Development
EFSR	-	Eastern Free State Region
IDW	-	Inverse Distance Weighting
JFM	-	January to March
LIA	-	Livelihood Indicator Approach
LVI	-	Livelihood Vulnerability Index
MK	-	Mann Kendall
OND	-	October to December
PRISMA- (PRISMA)	-	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SLF	-	Sustainable Livelihood Framework
SPI	-	Standardized Precipitation Index
SRSD	-	Sequential Regime Shift Detection
SS	-	Sen's Slope
TMD	-	Thabo Mofutsanyane District



# CHAPTER 1: INTRODUCTION

## Background

There is mounting evidence of shifting weather systems as climate change and variability become more pronounced. Empirical observations show that sea levels and temperature are increasing, while precipitation patterns are changing, and meteorological extreme occurrences such as drought and floods are recurring frequently (Mishra, Hussain, and Rasul 2016; Qaisrani et al. 2018). Studies have reported that natural disasters and exposure to numerous disasters namely landslides, floods, snow avalanches, and other types of mass wasting due to climate change are becoming regular in mountainous regions (Prasad et al. 2016; Stäubli et al. 2018; Thanh et al. 2020). Nevertheless, the effects of these disasters on mountainous communities vary depended on their exposure and susceptibility (Stäubli et al. 2018). Besides, there is inadequate evidence to link an increasing rate of natural disasters to climate change (Stäubli et al. 2018).

Mountainous landscapes are the most susceptible to the impacts of environmental change and fluctuation (Steiger et al. 2022). The ecological sustainability of mountains is increasingly compromised by global change, especially climate change, of which the environmental and physical systems in the mountain areas are extremely vulnerable (Schickhoff, Singh, and Mal 2016; Adelabu, Clark, and Bredenhand 2021). Global warming rates have been reported to be higher in mountainous areas than the global average, which has had a negative influence on the mountain biota, ecological processes, and cryosphere (Schickhoff, Singh, and Mal 2016). However, only a few studies have been conducted to show how local weather patterns are likely to change in complex mountain landscapes (Seidler, Sharma, and Telwala 2016; Singh 2017). These gaps in knowledge and data influence the prediction and intensity of extreme climate events, which constitute a significant hazard for local communities in mountain foothills (Xenarios et al. 2019). Also, there are only few studies demonstrating how climate change affects these regions because mountains are inaccessible and have few weather stations (Ullah et al. 2018; Mohamed and Mukwada 2019). As a result, many studies have considered relying on mountain communities' perceptions in surveys and interviews to explore local climatic trends (Huang et al. 2019; Poudyal, Dawadi, and Devkota 2019; Mijiddorj et al. 2020; Mkonda and He 2018; Kahsay et al. 2019; Sun et al. 2015). Furthermore, few studies have examined the variability of household perceptions on climate change in various altitudinal regions. Schneiderbauer et al. (2021) indicate that few studies have assessed risk perceptions in

communities in the same mountain range, communities in different mountainous regions, or communities in different elevation areas.

The effects of climate change on mountainous communities are directly felt in water, forestry products and agriculture (Piya, Joshi, and Maharjan 2016). Climate change is expected to exacerbate the existing vulnerabilities caused by various climatic and non-climatic drivers (Xenarios et al. 2019). Studies in the past have acknowledged the effects of climate shifts and variability on mountain livelihoods (Dendir and Simane 2019; Araro, Legesse, and Meshesha 2019; Ghosh and Ghosal 2020; Khalili et al. 2020; Singh 2017; Capitani et al. 2019; Said et al. 2019). However, there is inadequate information on how changes in climate impacts African mountains, mountain communities and ecosystems (Nsengiyumva 2019). The assessment of climate change effects in mountainous areas has mostly been single-disciplined (Palomo 2017). Thus, integrative strategies that dwell on climate change impacts on various ecosystem-based services in mountains are currently scarce (Palomo 2017). Call, Gray, and Jagger (2019) further point out that though our knowledge on how climate impacts influence rural livelihoods is growing, previous studies have been limited by an inability to consider both agriculture-based and off-farm livelihood approaches within the same context. Studies on climate change and variability on off-farm livelihoods, more specifically in mountainous regions, are relatively scarce.

Several other studies have shown that local communities are increasingly finding alternatives for income sources by combining agricultural and non-farm activities to sustain their livelihoods (Manlosa et al. 2019; Tolera and Senbeta 2020). However, such traditional livelihood strategies are becoming less sustainable in some communities as new weather and climatic extremes occur (Nembilwi et al. 2021; Ullah et al. 2018). Mohamed and Mukwada (2019) state that global adaptation assessments are rarely location-specific or relevant to the prevailing agro-ecosystem, and few explore what measures are needed to address system-specific threats. What remains uncertain is the effectiveness and long-term sustainability of local community adaptation methods in the context of climate variability and change. For example, Ayal et al. (2017), state that some existing adaptation measures are ineffective in times of extreme droughts where herders and farmers experience part of or entire crop loss and mass loss of livestock quantifying adaptation efficiency is difficult due to incomplete and scattered nature of our understanding of the adaptation and the vast time spans it must be measured (Mijiddorj et al. 2020; Dilling et al. 2019).

The Free State Province of South Africa is considered one of the main agricultural regions. Agriculture in the country support approximately 70% of the province's population for income, food, and employment, and is thus a crucial part for the food security and local economy (Cammarano et al. 2020). The effects of climate change are rapidly escalating in South Africa (Chersich and Wright 2019). Climate variability and change in the nation have caused changes in temperatures, precipitation, frequency, intensity and geographic distribution of severe events (Ziervogel et al. 2014; Ncube et al. 2016; Tabalaza 2017) and will continue to be a driver for change in the future. According to Cammarano et al. (2020), climate estimates for South Africa have shown a rise in temperature and increased rainfall variability. The country presents unique challenges to rural livelihoods, with marginalized rural communities likely to feel the more significant impact of climate change. However, in South Africa, information on climate change at the communal level, particularly in rural areas, is scanty (Ncube et al. 2016).

The impact of climate change creates significant problems for many South Africans and is expected to increase food insecurity, exacerbating poverty, especially among vulnerable rural communities (Turpie and Visser 2015; Ncube et al. 2016). In South Africa, several studies on the implications of climate change on the livelihoods of nature-based communities exist (Ubisi et al. 2017; Maluleke and Mokwena 2017; Ofoegbu et al. 2019; Nembilwi et al. 2021; Ndlovu et al. 2021; Talanow et al. 2020). However, most of these studies hardly relate specifically to mountain-region livelihoods.

Several authors have shown climate-related events in the Free State Province, South Africa, including the Maluti-Drakensburg Mountain. Low temperatures cause early onset of frost and late cessation of frost risks over the east and south-eastern section of the eastern Free State Region (Moeletsi, Tongwane, and Tsubo 2016). In Phuthaditjhaba, Qwaqwa, in the Eastern Free State Region, the communities reported very cold weather conditions during winter (Melore and Nel 2020). A significant increase trend in long-term yearly average maximum by  $0.03^{\circ}\text{C}$  and minimum temperatures  $0.02^{\circ}\text{C}$  was recorded in the Maloti-Drakensburg Region between 1960-2016 (Mohamed and Mukwada 2019). The rising temperature will result in increased evapotranspiration from water bodies (rivers, wetlands, and water reservoirs), reducing water source for local communities in the Qwaqwa area (Mohamed and Mukwada 2019). According to Melore and Nel (2020), climate change impacts in Phuthaditjhaba are associated with mounting summer temperatures and variations in rainfall, resulting in regular severe water shortages. Consequently, water scarcity is a burden to local communities, affecting water supply for domestic use, sanitation, and hygiene services. Crop models applied

to five different climate scenarios in the upland Bethlehem District (north-eastern area of the Free State Province) show that current maize production will be decreased by between 10% to 16% because of climate change (Cammarano et al. 2020). Thus, the projected climate change impacts in the Bethlehem District will threaten the economies of many who are dependent on rain-fed farming for sustaining livelihoods, thus increasing the food insecurity (Cammarano et al. 2020). However, information about climate change and variability impacts on the livelihoods of households in this mountainous region is scarce. There is a need for more detailed information about how the changing climate is affecting the livelihoods of mountain-based households across different elevation zones and settlement types. This study therefore seeks to contribute towards filling this gap.

In addition, there are very few studies, if any, that have sought to assess the effectiveness of adaptation methods used by communities in a mountainous setting, especially in the Eastern Free State Region of South Africa. There is a need for more detailed research regarding the effectiveness of the adaptation measures that might be employed by the local communities. Also, there is a need to formulate policies to maintain sustainable livelihood adaptations and alleviate poverty while protecting the natural resources upon which the mountain communities depend for survival. In this regard, the study aims to investigate the most preferred adaptation measures adopted by the local communities in Thabo Mofutsanyane District Municipality of South Africa, and the extent to which these strategies could be considered effective in building resilient mountain communities.

## **1.2 Problem Statement**

Adhikari, Baral, and Nitschke (2018) state that mountainous communities in low-income countries are considered susceptible to environmental change. In the mountainous Eastern Free State Region (EFSR) of South Africa, agriculture forms the primary source of livelihood for most communities, with most of the cultivation tending to be small-scale and subsistence (Tongwane et al. 2017). Most people's livelihoods face challenges of facilities and services, adverse climate, food deficiency, remoteness, lack of awareness, poor access to market and water stress (Rijal 2011). Climate change has become a threat to livelihoods, particularly in highly-agriculture dependent communities. The country is expected to face severe water insecurity, as it is one of the driest countries in Africa (Montmasson-clair, Mudombi, and Patel 2019). Furthermore, changes in climate are exerting pressure on the region's ecosystems and services, and on the communities' wellbeing and livelihoods (Nsengiyumva 2019). However,

there is a dearth of reliable information about how local weather patterns are likely to change in complex mountain landscapes (Seidler, Sharma, and Telwala 2016). According to Paul et al. (2019), rural households have long been discussed in scientific literature, although livelihood sustainability in marginal communities in remote and disadvantageous areas is scarcely researched.

Like mountain regions in the entire world, the EFSR of South Africa, is threatened by climate change. For instance, temperature increase (Matela 2015; Mukwada and Manatsa 2018; Mohamed and Mukwada 2019) and droughts (Botai et al. 2016; Mbiriri, Mukwada, and Manatsa 2018; Abubakar, Scholes, and Newete 2020) are some of the indicators of climatic change in the EFSR. This change has impacted on the livelihoods of communities, exposing them to low agricultural outputs, food insecurity and poverty. For this reason, an analysis of the potential effects of climate change on the livelihoods of the local communities is fundamentally significant for their survival (Suberi et al. 2018; Mukwada et al. 2020). Nevertheless, what has not been adequately covered is the degree to which climate change and variability are impacting livelihoods in the EFSR, specifically.

The impacts of climate variability and change are disproportionate and influence local livelihoods differently. Exposure to extreme events is location specific and communities settled in high, mid and low altitude regions are differentially affected (Bhadwal et al. 2019). Unfortunately, there is a scarcity of information about different adaptation strategies for different altitudinal regions (Gupta et al. 2019). Also, what remains unknown is how effective and sustainable adaptation measures implemented by rural communities in the midst of climate variability and change region are. Thus, more studies should be undertaken to explore the impact of specific climate-related events on rural livelihoods at different altitudes and how communities use available resources in effective ways to deal with climate change.

### **1.3 The Significance of the Study**

South Africa experienced a significant drought during the 2015-2016 period (Vetter, Goodall, and Alcock 2020). Droughts and floods, and their impact on rural livelihoods have been widely reported in the country. As mentioned in the preceding sections, rural communities make a significant part of their livelihood from rainfed small-scale/subsistence agriculture and pastoralism, which are substantially sensitive to climate change and variability. The impact of climate change may further aggravate the livelihoods of rural communities living in mountainous areas. Mukwada and Manatsa (2018) report that reliable climate information does not exist for a considerable part of many mountain areas. Given the nature of sparsely scattered

settlements and poor infrastructure, and the existing knowledge regarding climate change, research and assessment are least just where they are needed most (Pandey et al. 2017). The results of this research should provide valuable records on climate data that could be used for current and future studies in the region.

Studies that incorporate household perceptions and climate data have been found to be an important step towards adopting local-specific and appropriate adaptation options (Imran, Shrestha, and Datta 2020). Therefore, in this study, incorporating household perceptions in climate change studies will assist our understanding of how household perceptions are consistent with scientific information. Such an approach will enhance effective application of indigenous knowledge in developing sustainable climatic change adaptation measures. It is, therefore, critical to understand how local communities in the EFSR perceive climate change and its influences on their livelihoods, besides whether their perceptions are compatible with climatic data.

In the African mountains, there are no specific strategies for climate change adaptations (Nsengiyumva 2019). Hence, the findings of this study could be used to assess how the livelihood strategies that are already implemented could reduce the susceptibility of rural livelihoods to climate change and sustain the environment. Also, this study might be fundamental in designing mountain-specific adaptation plans that involve mountain communities in their design and implementation. Furthermore, this knowledge is imperative in drawing up sound policy measures and future strategies that seek to maintain sustainable livelihood adaptations without degrading the environment.

#### **1.4 Research Aim**

The aim of this study is to assess the strategies that have been adopted by rural communities in the Eastern Free State Region of South Africa to reduce the vulnerability of their livelihoods to climate change.

#### **1.5 Research Objectives**

1. To assess how the climate of the Eastern Free State Region has changed between 1960 and 2019.
2. To examine the effects of climate change and variability on the livelihoods of rural communities in the Eastern Free State Region.

3. To evaluate the effectiveness of adaptation strategies that have been adopted by the rural communities in addressing the impacts of climate change and variability on rural livelihoods in the Eastern Free State Region.
4. To draw up recommendations that could inform sound policy measures and future strategies that seek to maintain sustainable rural livelihood adaptations without degrading the environment in the region.

## **1.6 Research Questions**

1. How has the climate of the Eastern Free State Region changed between 1960 and 2019?
2. What are the effects of climate change and variability on rural communities' livelihoods in the Eastern Free State Region?
3. What adaptation strategies have been adopted by the rural communities in the region and to what extent can these strategies be considered as effective in addressing the impacts of climate change and variability on rural livelihoods?
4. What recommendations can be offered to inform sound policy measures and future strategies that seek to maintain sustainable livelihood adaptations without degrading the environment in the region?

## **1.7 Hypotheses**

H<sub>0</sub> The climate of the Eastern Free State Region has not changed between 1960 and 2019.

H<sub>1</sub> The climate of the Eastern Free State Region has changed between 1960 and 2019.

H<sub>0</sub> Climate change and variability have no effect on the livelihoods of rural communities in the Eastern Free State Region

H<sub>1</sub> Climate change and variability have an effect on the livelihoods of rural communities in the Eastern Free State Region

H<sub>0</sub> The livelihood strategies that have been adopted by rural communities in the Eastern Free State Region are not effective in combating the effects of climate change and variability

H<sub>1</sub> The livelihood strategies that have been adopted by rural communities in the Eastern Free State Region are effective in combating the effects of climate change and variability.

H<sub>0</sub> No recommendations can be made to improve effectiveness of the livelihood strategies and policy strategies that will help rural communities to improve their capacity to cope with climate change and variability in the Eastern Free State Region without degrading the environment in the region.

H<sub>1</sub> Recommendations can be made to improve effectiveness of the livelihood strategies and policy strategies that will help rural communities to improve their capacity to cope with climate change and variability in the Eastern Free State Region without degrading the environment in the region.

### **1.8 Methodology used in the study**

The study used both quantitative and qualitative research methods. In this mixed methods approach, three methods were employed to gather the data: questionnaire surveys, interviews, and climate data. The Sustainable Livelihood Framework was used to frame the research study. The analysing of temporal variation of climate variables (temperature and rainfall) was done for the period 1960-2019. Maximum temperatures (T<sub>max</sub>) and minimum temperatures (T<sub>min</sub>) and rainfall climate data were attained from the Climate Explorer's Climate Research Unit (CRU) gridded data file at spatial resolution of 0.5° X 0.5°. The study used multi-stage sampling that involved selecting the study sites according to elevation, population size and settlement types. The study used different statistical approaches to assess the spatiotemporal changes in T<sub>max</sub>, T<sub>min</sub>, precipitation and drought extremes. The non-parametric Mann Kendall (M.K) test was used to determine the presence of a trend in mean maximum and minimum temperatures and precipitation indices. Standardized Precipitation Index (SPI) was used to determine the frequency of drought. Data from the questionnaire survey were captured, processed, and statistically analysed for descriptive statistics (frequencies and percentages) following the coding of the responses of respondents to different closed-ended questions. The analysis was done in Microsoft Excel 2016 and SPSS (Version 17.0) environments. The Pearson Correlation, T-test and logistic regression were used for statistical analysis.

### **1.9 Organizational structure of the thesis**

This thesis consists of six chapters:

Chapter 1 presents the introduction of the research study, comprising the problem statement, research aim, objectives, questions, and the significance of the study. Chapter 2 covers the literature that was reviewed as part of the study. That chapter focuses on the geographic origin of the research literature on the impacts of climate change and variability on rural livelihoods, the thematic results of the reviewed literature, and lastly the convergence and divergence of the literature globally. Chapter 3 provides an analysis of temperature and precipitation shifts and drought episodes that have occurred in the eastern part of the Free State Province between 1960 and 2019. This chapter also assesses the compatibility of the perceptions of local communities in the region with the climate data. Chapter 4 highlights the results of the questionnaire survey that was conducted on the impacts of climate change and variability on the livelihoods of the local communities. Chapter 5 turns attention to the adaptation measures implemented by the rural households at different scales and evaluates the extent to which these adaptation strategies could be considered effective in building resilient mountain communities. Chapter 6, the last chapter of the thesis, summarizes the results of the study and presents relevant recommendations that could guide further studies on climate change adaptation in mountain environments.

## CHAPTER 2: THEMES IN CLIMATE CHANGE AND VARIABILITY WITHIN THE CONTEXT OF RURAL LIVELIHOODS. A SYSTEMATIC LITERATURE REVIEW.

### 2.1 Brief chapter synopsis

This chapter is based on the paper which was published as:

Msimanga, L., and Mukwada, G. (2022). Themes in climate change and variability within the context of rural livelihoods. A systematic review. *Research in Globalization Journal*. p:100101. <https://doi.org/10.1016/j.resglo.2022.100101>

### 2.2 Abstract

Rural livelihoods will continue to face the consequences of climatic change in the short and long term, and the outlook is likely going to deteriorate further with the increasing frequency and intensity of weather extremes. This paper aims to investigate the common traits and heterogeneity of climate change impacts on rural livelihoods across the globe. This study focused on systematically reviewing 86 publications using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. The review of these articles resulted in the identification of 4 main themes and 11 sub-themes. The results indicate that the substantial body of literature on climate change and rural livelihoods emphasizes the vulnerability of natural-resources based livelihoods to climate-related impacts. Our analysis found that worldwide, the indicators of climate change and variability vary in terms of how climate change affects rural livelihoods and accordingly how rural communities cope with or adapt to climate change also differ. Based on the analysis, the study concludes that these differences are attributed to exposure to various climate change conditions and non-climatic factors, namely social, economic, cultural, and political factors. To employ effective and sustainable rural livelihoods in the face of climate-induced events, it is crucial for internal and external institutions to recognize such heterogeneity, making the formulation of adaptation plans and policies context-specific.

**Keywords:** Systematic review; Climate change; variability; rural livelihoods; rural communities; adaptation

### 2.3 Introduction

Climate change and variability continue to be a matter of global concern due to the challenges they pose in all economic development sectors. While climate change is witnessed as a long-term alteration in climatic conditions, climate variability is the fluctuations experienced in

weather patterns in a short period of time at a given location (Kolawale et al. 2016). It should be noted that climate change has been broadly accepted to result in increased frequency and intensity of climatic extremes, the same features that define climate variability (Kandji, Louis, and Mackensen 2006). This is in align with (Yohannes, Teshome, and Belay 2020), who state that climate change and variability are evident through decreasing precipitation, increasing temperatures and increasing frequency and intensity of droughts, floods, and heatwaves.

Climate change and variability has become a significant challenge for rural livelihoods worldwide (Ateeq-ur-rehman et al. 2018). As a result of the different effects of climate change and variability, rural livelihood activities that directly depend on natural resources, such as agriculture, land, water, and forests, are adversely affected globally (Hossain et al. 2018; Tolera and Senbeta 2019; Saalu, Oriaso, and Gyampoh 2020). Some of the effects of climate change and variability on agriculture-based livelihoods include increased crop pests and diseases, reduced crop and forage productivity, crop failure, livestock diseases and livestock mortality. Climate change and variability affect the overall health of the ecosystem and reduce the supply of forest resources such as foods, fuelwood, medicinal herbs, and other non-timber forest products (NTFPs), which will impose additional stress to the forest-dependent livelihoods (Dhungana et al. 2020).

Social, cultural, and economic threats emanating from climate change and variability have been reported in terms of reduced health, changes in food availability and food affordability, reduced labour, erosion of cultural norms and isolation from social functions, among other variables (Sowah et al. 2020). Climate change affects health by enhancing water scarcity and reliance on unsafe water sources, including saline groundwater (Singh et al. 2019).

Substantial evidence shows consequences of climate change and variability on rural livelihoods. However, Abdulai, Ziemah, and Akaabre (2017) state that the complicated relationship between climate change and rural livelihoods needs to be further examined. The literature on this matter is enormous. Thus, constant exploration of this area is required due to the diversity of the relationship between the two in different parts of the world (Abdulai, Ziemah, and Akaabre 2017). The manifestation of climate change varies, including how it affects livelihoods and how people cope with and adapt to climate change also differ.

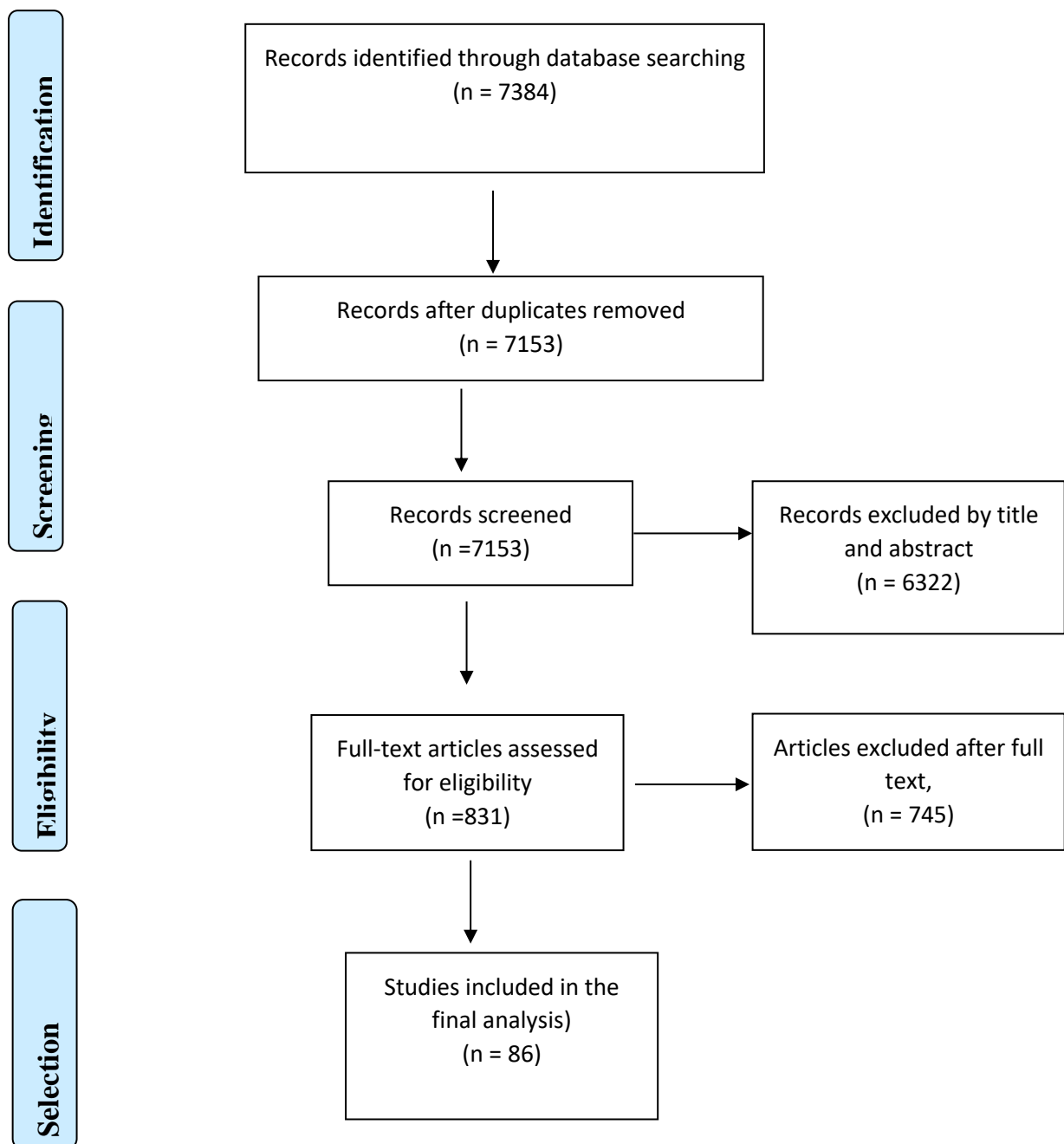
Climate change and rural livelihoods have been the subject of several studies. Most of these evaluations, however, have concentrated on a specific impact, such as food security (Hatab et al. 2019; Kogo et al. 2021), crop productivity (Karki, Burton, and Mackey 2020), livestock

(Escarcha et al. 2020), and fisheries (Liu, Borazon, and Muñoz 2021). Unlike most reviews done, this review demonstrated to recognize the common traits and heterogeneity across the globe and the reasons behind the diversity in climate change and rural livelihoods. A systematic review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines on climate change and rural livelihoods. The aim of the systematic review adopted in this paper is to identify the empirical evidence that fits the pre-specified inclusion criteria to answer specific research questions or hypotheses (Snyder 2019). This paper addresses specific research questions. 1. What is the geographical origin of recently published literature on the relationship between climate change and rural livelihoods and how is this literature geographically distributed at global level? 2. What are the similarities and differences between literature on climate change - rural livelihoods nexus from different parts of the world? Thus, the study explores the socio-economic implications of climate change indifferent regions of the world. Also, the study compares the top-bottom and bottom-up approaches to climate change adaptation in different global regions.

#### **2.4 Methodology**

A systematic methodology, namely the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (**Figure 2.1**), was adopted to identify and analyse the available literature on climate change and rural livelihoods. Several environmental studies have adopted PRISMA guidelines, particularly in literature reviews (Hassan et al. 2019).

The PRISMA Statement comprises a 27-item checklist and a four-phase flow diagram (Figure 2.1), which are essential for reporting a systematic review (Liberati et al. 2009). The PRISMA model uses systematic methods to reduce bias, hence providing reliable findings from which conclusions and decisions can be made (Liberati et al. 2009).



**Figure 2.1** An adapted version of the Preferred reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology approach (Moher et al. 2009)

#### 2.4.1 Identification of articles

A comprehensive literature search was done using relevant peer-review literature and grey literature published from seven electronic databases, including Scopus, Web of Science, Google Scholar, Sage Publisher, JSTOR, Springer, and ISI Proceedings. Grey literature

included unpublished theses, reports, conference proceedings, unpublished book chapters and e-books. To identify the relevant articles, searches for keywords such as 'climate change', 'climate variability', 'rural livelihoods', 'adaptation', and search phrases such as 'climate change impact on rural livelihoods', 'adaptation strategies to climate change', 'climate variability and rural livelihoods' were undertaken. The search for keywords and phrases was guided by the purpose of the review and research questions noted above. Peer-reviewed articles published after 2016 were included in the review. After entering relevant keywords, the current work retrieved 7384 articles from all the databases.

#### 2.4.2 Screening

The number of sources retained and excluded in the review process were recorded based on the PRISMA Statement (**Figure 2.1**). The keywords search yielded 7384 articles from the databases. Screening was done, to remove duplicates. After excluding 231 duplicates, 7153 studies were selected based on the first stage of the screening. All irrelevant articles were excluded. A total of 6323 articles were excluded and only 831 articles were retained and whole texts read. A total of 745 articles were eliminated after full text reading, resulting in the final set of 86 eligible papers that were considered for in-depth analysis.

#### 2.4.3 Criteria for eligibility

To avoid duplicates and select relevant articles, the inclusion and exclusion criteria were used. Only empirical studies conducted on climate change and variability and rural livelihoods were included in this review. Since the review focused on climate change and rural livelihoods, articles on urban livelihoods were excluded. Excluded were studies that explicitly focused on determinants or constraints to climate change adaptations. The study only included peer reviewed articles and excluded review articles. Peer review journals published in English were included and non-English articles were excluded. Articles which were not available in full text were also excluded. All documents published before 2016 were excluded. We acknowledge that the paper might be based on a limited selection of articles. Based on the exclusion and inclusion criteria applied in this review, 86 articles were deemed eligible for review (**Table 2.1**).

**Table 2.1** Criteria for inclusion and exclusion of literature

Criteria	Included	Excluded
Date of publication	Peer reviewed journal articles after 2016	Peer reviewed articles published before 2016

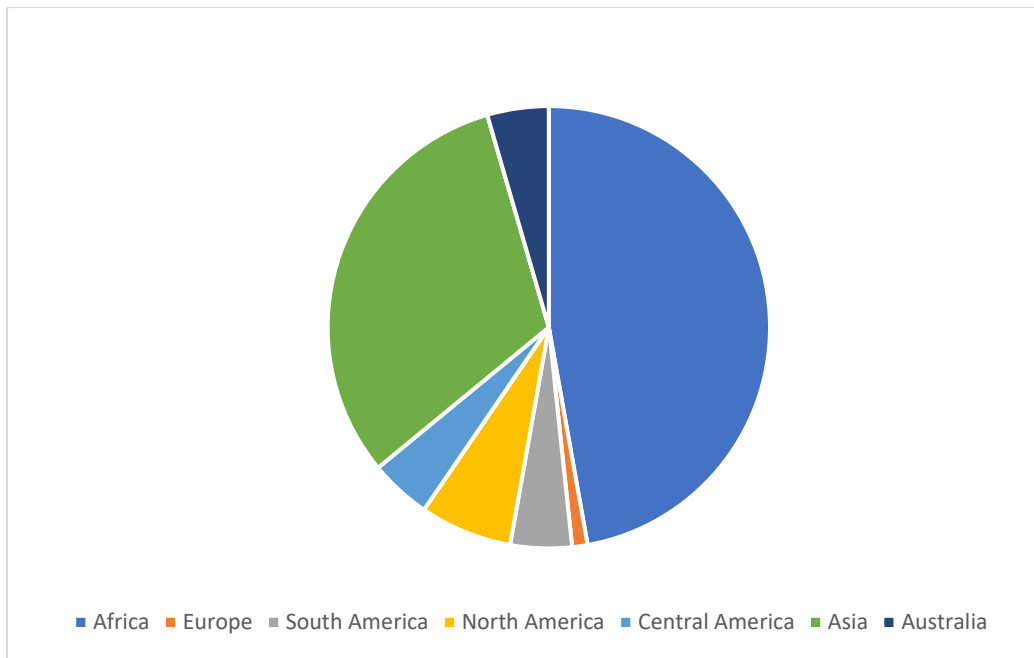
Language of publication	Peer reviewed journal articles written in English	Non- English Articles
Type of articles	Only peer reviewed articles available to the authors in full text	Non-peer reviewed journals, articles not available to the author in full text
Accessibility of articles	Articles accessible through the electronic databases (Scopus, Web of Science, Google Scholar, Sage Publisher, JSTOR, Springer, ISI Proceedings)	Not accessible through these databases
Main theme of the publication	Articles specifically focussing on the impacts of climate change and variability on rural livelihoods and adaptation strategies	Articles that did not specifically focus on the impacts of climate change and variability on rural livelihoods and adaptation strategies

## 2.5 Research Results

This section presents the results of the literature review in the following (1). Geographic origin of the literature, (2). Thematic results of the literature, and (3). Convergence and divergence of the literature across the globe.

### 2.5.1 Geographic origin of the literature

Regarding the geographic origin of the articles, **Figure 2.2** shows that the majority of the 86 studies that were conducted emanated from Africa (n=39), followed by Asia (n=28), South/North America (n=15) and a few in Australia (n=4). Out of the 39 studies that were conducted in Africa, Ghana (10), Ethiopia (7), Tanzania (4), Botswana (3) and Kenya (3), two studies from South Africa and Nigeria, while each of the remaining studies were conducted in Uganda, Senegal, Tunisia, Burkina Faso, Zambia, Namibia, and Kenya. Only one study was conducted in Eritrea, Ethiopia, South Sudan, Sudan, Tanzania, and Somalia. In Asia, most of the publications reviewed were conducted in India (6), Bangladesh (5), Pakistan and Nepal (4) and Vietnam (3). The remaining seven studies were conducted in Bhutan, China, Cambodia, Philippines, Barisal, Afghan, and the Mekong River Basin.

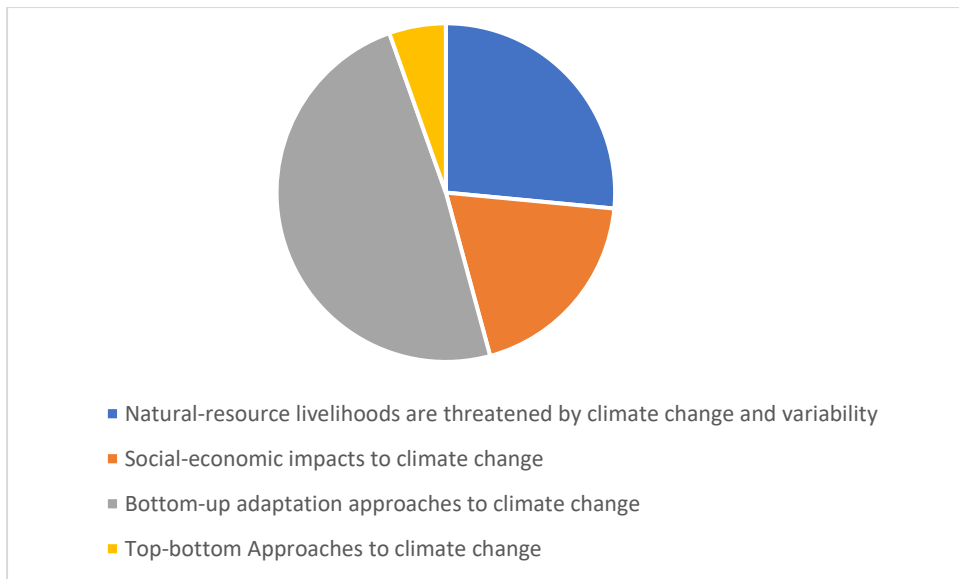


**Figure 2.2** Geographical origin of the literature on the relationship between climate change and rural livelihoods (N=86)

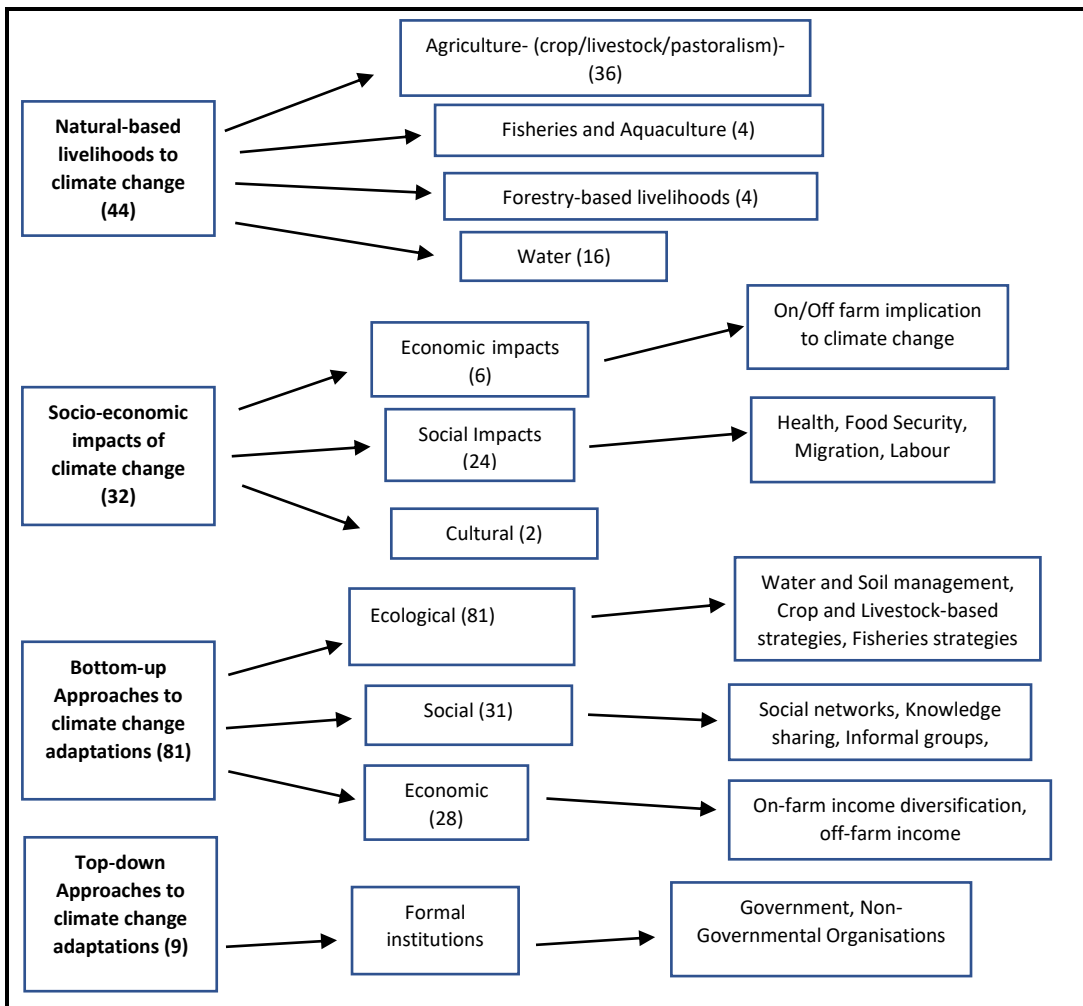
Out of the six studies conducted in North America, five were conducted in the United States and one in Canada. Of the four studies conducted in South America and Central America, in Peru (2), Guyana (1), and the Amazon floodplains of Brazil (1). Among the studies that were conducted in Central America, two were conducted in Mexico, one in Haiti and one covered three countries (Costa Rica, Honduras and Guatemala). Only one study was conducted in Europe, based on Serbia. In all the four studies that were conducted in Australasia, two articles were conducted in Fiji, while the other two were conducted in Papua New Guinea and South Australia.

### 2.5.2 Thematic Coverage

**Figure 2.3** presents the results of the thematic analysis of the reviewed literature; four themes and 11 sub-themes were identified in this review. The themes (**Figure 2.4**) include natural-based livelihoods threatened by climate change and climate variability (4 sub-themes); socioeconomic aspects of livelihoods to climate change (3 sub-themes); bottom-up approaches to climate change adaptation (3 sub-themes), and top-down approaches that shape adaptation strategies (1 sub-theme). The themes used in this review are significant because they are universal and consistent with the categories provided to climate change and rural livelihoods across the globe.



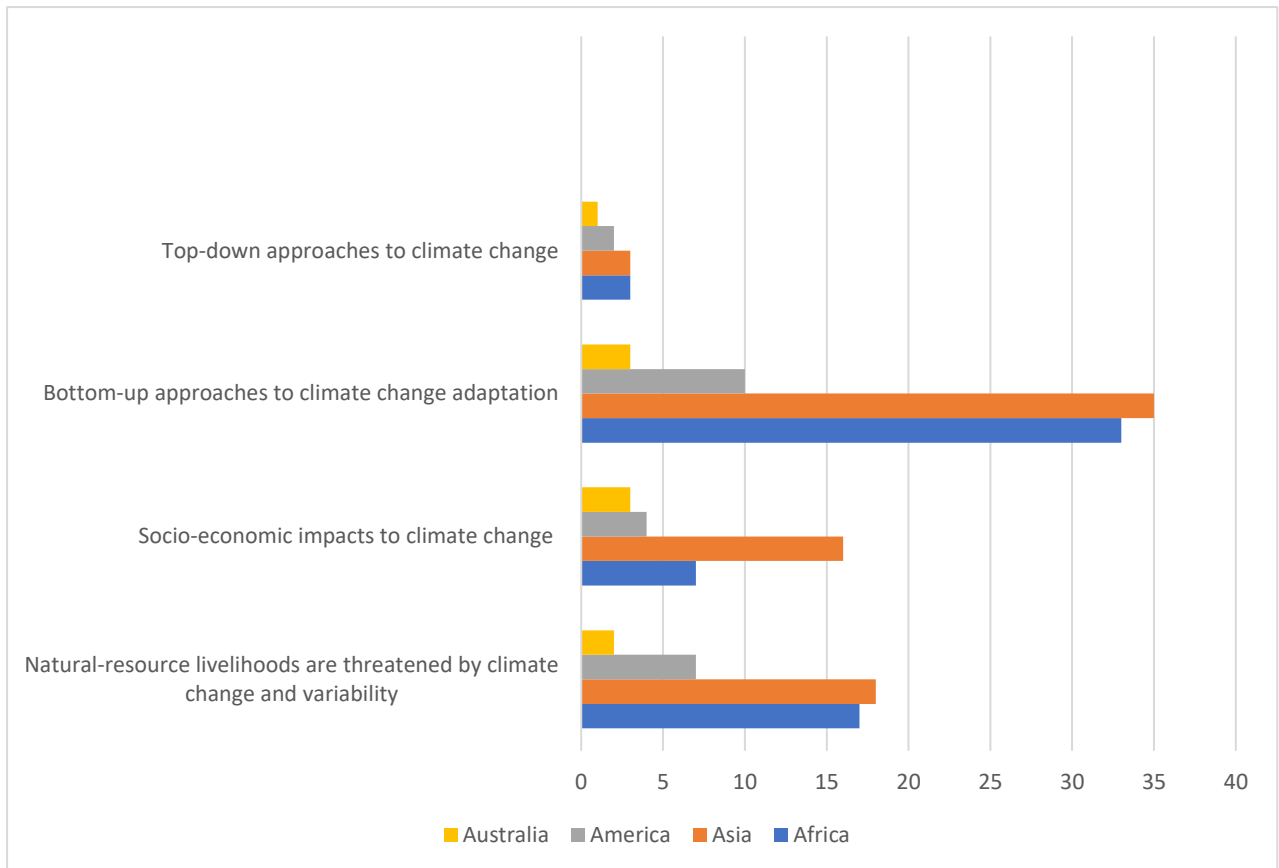
**Figure 2.3** Thematic coverage of literature on climate change – rural livelihood nexus (N=86)



**Figure 2.4** Classification of Themes and Sub-themes

## 2.6 Differences in themes based on the geographic regions of the world

The results (**Figure 2.5**) indicate that most of the eighty-one publications focused on on-farm management strategies to climate change and variability, Africa (33), Asia (35), South and North America (10) and Australia (3). Forty-four studies focused on climate change and natural-based resources, Africa (17), Asia (18), South and North America (7) and Australia (2). Forty-two studies (Africa (22), Asia (15), South and North America (4) and Australia (2)) focused on off-farm livelihood diversification. Thirty publications reported on the socioeconomic impacts of climate change, Africa (7), Asia (16), South and North America (4) and Australia (3).



**Figure 2.5** Different themes based on the geographic regions of the world

A few studies (9) on top-down approaches to climate change adaptations, Africa (3), Asia (3), South and North America (2) and Australia (1).

### *2.6.1 Natural resource livelihoods are threatened by climate change and climate variability*

Evidence reveals that climate change has implications for people's livelihoods, agriculture, freshwater supply, and other natural ecosystems that are crucial for human subsistence (Thinda et al. 2020). Natural resource-based livelihoods consist of livelihoods that are derived from natural ecosystems. Under this theme, four sub-themes were identified, namely agriculture dependent livelihoods (crop/livestock/pastoralists) (36), fisheries/aquaculture (4), forest-based livelihoods (4), and water (16). Almost all the studies worldwide stated that rural communities that depend on natural-based resource livelihoods are the most vulnerable to climate change.

The analysis of the reviewed literature shows that climate change has implications for different agricultural-based livelihood systems such as crop-based livelihoods (Oviedo et al. 2016; Stričević et al. 2020; Michaelsen et al. 2020), pastoralists (Berhe et al. 2017; Napogbong et al.

2020), Natural-resource livelihoods are threatened by climate change and variability and livestock-based livelihoods (Son and Kingsbury 2020; Aryal et al. 2020). Other natural based livelihoods from the analysis include forest-dependent livelihoods (Negi et al. 2017; Pandey et al. 2018; Dhungana et al. 2020), and fisheries (Haque et al. 2019; Huynh et al. 2021). The analysis revealed profound impacts of climate change on crop production, including shifts in the length of the growing and harvesting season, crop failure, reduced crop yields, increased crop pests and diseases, low income, and increased food prices.

Most pastoral livelihood systems in the arid and semi-arid regions of Tanzania, Ethiopia and China highly depend on limited natural resources such as pasture, fodder, forest products and water (Mkonda and He 2016; Chen et al. 2018; Tolera and Senbeta 2019). However, due to climate change induced events, many livestock and pastoral-based livelihoods are exposed to livestock diseases, natural disaster-related injuries and death, reduced herds and shortages of forage (Inman, Hobbs, and Tsvuura 2020; Son and Kingsbury 2020). Most rural livelihoods in developing countries are based on forests, agro-ecosystems, water resources, and ecosystem goods and services (Adhikari, Bara, and Nitschke 2018). Thus, the interaction between climate change and forest-dependent communities cannot be underestimated (Saalu, Oriaso, and Gyampoh 2020). However, climate change and variability present difficult challenges to forest dependent livelihoods (Dhungana et al. 2020). Recent studies point out that climate change affects the ecosystem's health and reduces the supply of forest resources such as foods, fuelwood, medicinal herbs and NTFPs (Pandey et al. 2018; Dhungana et al. 2020). Fishers in Lake Wamala, Uganda, asserted that droughts' impacts on fishing communities include reduced fish catches and sizes and loss of human lives (Musinguzi et al. 2016). In contrary, the same study reported that though floods resulted in increased fish yields and size, they contributed to loss of fishing gear, and damaged gear and landing sites (Musinguzi et al. 2016). In Asia, climate change induced tropical cyclones and tidal surges are responsible for destroying wild and cultured freshwater fish, and reduced diversity of coastal and freshwater fish, shellfish, crab and shrimps and eased access to water for domestic purposes (Hossain et al. 2018; Huynh et al. 2021). Local households perceived a decline in fish catch over time, leading to decrease in their income from marine fishing and other fishing-related activities such as fish sauce making (Huynh et al. 2021). The fishing households in Phu Dien confirmed themselves more difficult in diversifying local-based non-fishing activities because of limited access to cultivated land and few job opportunities. In Quang Cong, the higher number of the households could conduct some local-based non-fishing activities with small plots of land for

vegetable crops or poultry raising or they did some small-scale trading for petty income (Huynh et al. 2021) Climate change impacts cause reduced water availability, accessibility, supply, and demand for the rural communities, leading to impeding water access for livelihood strategies. Research conducted in the Kilombero, Mbinga and Mbozi Districts of Tanzania, as well as in the Limpopo Province of South Africa, revealed that droughts, unpredictable rainfall changes and increased temperatures resulted in reduced water levels in natural springs, rivers and boreholes, leading to limited water availability (Balama et al. 2016; Kangalawe 2017; Rankoana 2020).

Several studies from Asia also described cases of climate change implications for water sources, where both surface and groundwater sources were affected by increased salinity and drying up of water sources, resulting in decreased quantity and quality of water for irrigation and drinking (Sapkota et al. 2016; Bhattachan et al. 2018; Shahzad et al. 2019; Chhogyel et al. 2020). Similarly, research from Papua New Guinea and Fiji highlighted climate-related challenges posed by a decline in water quantity and quality in rural communities, thus compromising household domestic activities (Gwahirisa, Pamphilon, and Mikhailovich 2017; Currenti et al. 2019).

### *2.6.2 Socio-economic aspects of livelihood to climate change*

Climate-associated shifts in livelihoods affect the social and economic systems of rural communities. Indirectly, climate change impacts socio-cultural and economic systems and worsen rural poverty, as well as pose changes in health status, income levels, food security, gender-biased activities, competition for resources and erosion of cultural activities (Chen et al. 2018; Singh et al. 2020). In this case, the study identified three sub-themes that illustrate the indirect impacts of climate change on rural livelihoods, including social impacts (24), economic impacts (6), and cultural impacts (2). Social impacts to climate change include migration, labour, health, food security, and the results show a high number of studies regarding climate-related implications to social systems than economic and cultural impacts. Despite the importance of non/off-farm diversification to rural livelihoods, climate change impacts on non-farm activities are limited (6).

Climate stressors have also triggered migration in rural communities. In northern Ethiopia, droughts increased the temporary migration of rural communities to cover immediate needs like food shortages (Hermans and Garbe 2019). Although, Hermans and Garbe (2019) highlight limited studies regarding the importance of one specific climatic factor such as drought with

other non-climatic factors that shape migration processes, they identified key socio-economic reasons for migration, including searching for alternative sources of income, and seeking or improving education. Sobczak-szelc and Fekih (2020) state that a deeper understanding of the ongoing processes that push people to migrate is still needed.

Migrations induced by climate change and variability reduces labour availability in rural communities. Labour shortages are also attributed to the temporary or permanent migration of young or able-bodied men (Bezu et al. 2019; Le and Vo 2019; Silveira, Ibarra, and Carrillo 2020). Heat stress incidents increase physical and mental tiredness, resulting in difficulties in doing domestic chores, increased working hours, and work exhaustion, thus reducing the efficiency of farm labourers. Increased workload due to limited availability of resources; for example, communities in Lawra District, Ghana and Satkhira District, Bangladesh, walk long distances to fetch water during dry seasons (Abdulai, Ziemah, and Akaabre 2017; Haque et al. 2019). Another case study from western Ghana found that taking the animals out into distant fields, building, or repairing kraals, daily milking lactating cows and closely nursing sick and wounded animals increased labour to pastoralists (Napogbong et al. 2020). Consequently, increased labour raises production costs, decreases productivity, and lower economic returns. Climate change increases incidents of human health through heat stress, water and salinity related diseases (Abaje et al. 2016; Khayyam and Noureen 2020). As a result, climate-induced ill health causes loss of income due to incapacitation, and the use of scarce resources for health instead of investing in improving the livelihoods of rural communities. However, as mentioned earlier, the impacts of climate change-induced water scarcity on health and well-being are multifaceted (Abedin et al. 2019).

Food insecurity is one of the social impacts of climate change. Food shortages, changes in the food quantity and availability and increased food prices reduce household income, worsening livelihood insecurities (Aniah et al. 2016; Hermans and Garbe 2019). Studies in Fiji, Central America, Cambodia, and Vietnam, respectively, reported the adverse effects of climate change on food quantity, availability and quality, leading to insufficient nutrition intake (Ezenwa et al. 2018; Harvey et al. 2018; Currenti et al. 2019; Henningsen, Pauli, and Chhom 2020).

Climate anomalies indirectly decrease household income attained from cash crops such as vegetables, coffee, grapes, berries, and cocoa (Gwatirisa, Pamphilon, and Mikhailovich 2017; Bardsley, Palazzo, and Pütz 2018; Amfo and Ali 2020). Climate-induced impacts on tourism have resulted in increased labour requirements and lessened incomes for rural communities in

Khyber Pakhtunkhwa Province, Pakistan (Shahzad et al. 2019). Besides, climate change increases market prices and affects non-farm activities such as cargo carriers, taxi drivers and bricklayers (Harvey et al. 2018; Silveira, Ibarra, and Carrillo 2020). Also, rural communities incur huge debts and increased farm investments (Abdulai, Ziemah, and Akaabre 2017; Singh et al. 2019). Likewise, rural communities face increased healthcare costs and limited primary services such as schools, markets, and hospitals (Gwatirisa, Pamphilon, and Mikhailovich 2017).

Apart from the social impacts discussed above, climate change and variability influence cultural systems in rural communities. For example, (Bhattachan et al. 2018) noted the impacts of sea-level rise on cultural heritage tourism in Albemarle-Pamlico Peninsula, North Carolina. In Limpopo Province, South Africa, rural communities stated that their cultural practices were negatively affected because of the loss of livestock production due to water scarcity (Rankoana 2020).

### *2.6.3 Bottom-up approaches to Climate change Adaptations*

The severe impacts of climate change and variability on rural livelihoods have resulted indifferent on-farm adaptation strategies meant to reduce livelihood vulnerability. Bottom-up tactics are used to interpret and react to what local communities are experiencing in the context of their specific environment, social variety, and cultural diversity. As a result, three subthemes were identified: social (31), economic (28) and ecological (84) climate change approaches. The review discovered several studies on ecological management techniques for climate change, including soil and water management, fisheries management, and crop and livestock management strategies, demonstrating the importance of natural-based livelihoods to communities around the world.

Indigenous knowledge systems (IKS) have been widely appreciated by rural communities concerning adaptation strategies for coping with climate change and variability. Local communities possess detailed knowledge of their environment developed from personal observation, culture and experience, including shared experience among community members (Velepini, Smucker, and Clem 2018). According to the findings, the adoption of IKS as a bottom-up method to climate change adaptation is concentrated in Africa and Asia and restricted in South and North America and Australia. Despite the fact that the use of IKS for climate change adaptation has attracted widespread attention, there is no uniformity in its application to mitigate the effects of climate change. For example, communities in the Ba Be

District of Bac Kan Province, Vietnam, use IKS and experience to adapt to floods through altering planting dates and times, and use local crop varieties to suit changing conditions (Son and Kingsbury 2020). In western Ghana, Fulani herders implement indigenous adaptation strategies such as mobility, diversified feeds, stress management to reduce heat in livestock and by sharing labour (Inman, Hobbs, and Tsvuura 2020). However, the capacity of IKS in adapting to climate change is likely to be surpassed by increased climate-related risks (Mubiru et al. 2018), and external factors such as markets, technology, and governance.

Many rural communities have modified their behaviour and their environment to adapt to their local climatic conditions (Son and Kingsbury 2020). For instance, in Alona, Papua New Guinea, rural households identified differences in the food consumption patterns during drought and non-drought periods (Gwatirisa, Pamphilon, and Mikhailovich 2017). Some of the changing practices include using biogas instead of firewood and switching from traditional food crops to multipurpose cash crops and vegetables (Adhikari, Baral, and Nitschke 2018). However, little is known about how these traditional coping measures translate into adaptation to long-term changes and the extent to which they limit transformational responses to climate change (Pandey et al. 2018).

Another form of adaptation is on-farm income diversification (14), referring to reliance on different sources of income, including those related to use of natural resources. Examples include selling charcoal, fuelwood, livestock, reeds and thatching grass to generate income/buy food, timber production, tree nurseries, honey production, and on-farm labour (Ombogoh et al. 2018; Araro, Legesse, and Meshesha 2019). However, it is important to note that most of these on-farm adaptation strategies generally become ineffective or unstable due to unpredictable climate risks.

In response to climate change on crop and livestock production, rural communities have developed local-based crop management strategies (43) and livestock related adaptation (11) to sustain their rural livelihoods. To deal with uncertainties and risks of climate change and variability, scholars globally have reported on the following strategies: introduction of drought/flood/ salinity-resistant crops; early maturing crop varieties; hybrid seeds; as well as growing of vegetables, growing shade trees, different crop varieties, and changing planting dates, (Raghuvanshi and Ansari 2017; Jawid and Khadjavi 2019; Escarcha et al. 2020; Mukwada et al. 2020). However, (Ochieng et al. 2020: 1107) state that diversifying crop

production is not a ‘one-size-fits-all’ strategy, but should consider high outputs, existing land-use policies and known benefits from specific crop species.

The review reveals that local communities implemented soil management (14) and water management activities (26). Soil moisture conservation techniques include reducing or eliminating the use of fertilizers and pesticides and using practices such as mulching, crop rotation, intercropping, applying manure and using improved crop varieties (Sapkota et al. 2016; Saguye 2017; Papa, Nzokou, and Mbow 2020; Mubiru et al. 2018). Related to water conservation practices, studies have mentioned digging of wells and ponds, harvesting water during the rain using buckets, water tanks and Ferro-cement astern, pumping water out of the fields, and altering or adding irrigation (Dumenu and Obeng 2016; Takahashi et al. 2016; Bunclark et al. 2018; Bedeke et al. 2019; Mahdu and Mills 2019). However, drilling of new wells is costly and subartesian wells, add costs to water pumping (Sobczak-szelc and Fekih 2020). While in Bac Kan Province, Vietnam, rural communities used bamboo pipes to move water for irrigation and household purposes, hence fewer costs and labour required (Son and Kingsbury 2020). Interestingly, in the Nepal, tree planting is considered the prominent strategy for safeguarding water sources for consumption and agriculture (Dhungana et al. 2020). These water conservation strategies demonstrate how local communities can efficiently employ available resources to mitigate the effects of climate change and variability.

Traditional methods used in grain storage and food preservation are used to cope with periods of hunger and to secure seeds for successive cropping seasons following severe droughts (Mubiru et al. 2018). In Papua New Guinea, rural communities engage in food preservation methods and share scarce resources amongst themselves (Gwatirisa, Pamphilon, and Mikhailovich 2017). Another example is that of Bongo District, Ghana, where rural communities use plant extracts to store and preserve grains (Aniah, Kaunza-Nu-Dem, and Ayembilla 2019). However, such methods are less effective during periods of diseases and pest outbreaks, resulting in food and seed shortages (Mubiru et al. 2018).

#### *Economic strategies employed by rural communities to Climate change*

Implementing off-farm diversification strategies in rural communities is widely reported in literature. Off-farm rural livelihood diversification can be based on natural resources, but opportunities for their use in coping with climate change remain limited in developing countries (Son and Kingsbury 2020; Yiridomoh, Sullo, and Bonye 2021). Under this sub-theme, three categories were obtained, namely wage income (22), self-employment (15), migration (23).In

Asia, self-employed based activities linked to tourism, trading, shop ownership, moneylending, land leasing and hiring out farm machinery such as power pumps, threshers and tractors were observed in Barisal, Vietnam, China, Bangladesh, Pakistan and India (Kabir, Alauddin, and Crimp 2017; Luqman et al. 2017; Sheikh and Akter 2017; Shahzad et al. 2019; Khayyam and Noureen 2020; Sons and Kingsbury 2020). Meanwhile, in African rural communities, some of the self-employed activities include stone quarrying, sand mining, masonry, carpentry, dressmaking, shoe repair and motor/bicycle fitting and repairing (Moroda, Tolossa, and Semie 2018; Hermans and Garbe 2019; Amfo and Ali 2020). Concerning wage labour, studies highlight employment opportunities such as carpenters, herdsmen and bricklayers undertaken by rural communities (Kabir, Alauddin, and Crimp 2017). Based on the review, the analysis shows that there are a significant number of studies that acknowledge the implementation of off-farm activities compared to studies that assess how these activities might be impacted by climate change.

Existing evidence shows that migration is one of the off-farm strategies that rural communities adopt, mostly where their rural livelihoods heavily depend on climate variability (Jha, Gupta, and Chattopadhyay 2018; Bezu et al. 2019). In rural communities within the Mekong Delta, Vietnam and El Faouar Region, Tunisia, temporary or permanent out-migration to the cities is seen as a livelihood adaptation strategy to climate change (Le and Vo 2020; Sobczak-szelc and Fekih 2020). However, Sobczak-szelc and Fekih (2020) argue that migration does not have to be the last option to curb environmental changes but provides financial resources for adaptation. Besides generating remittances, migration provides opportunities to acquire knowledge on new techniques and farming practices to enhance agricultural income (Jha, Gupta, and Chattopadhyay 2018).

#### *Social related activities implemented to cope with climate change*

As the impacts of climate change and variability are projected to worsen, more social-related measures will be implemented by rural communities to safeguard their livelihoods. According to the review, four categories under this sub-theme were developed, namely remittances from migration (23), social relationships (20), cultural activities (2), food and water security (22). The review found access to social relations through familial networks and communities lessens the burden of climate change and extreme weather events (Currenti et al. 2019; Sowah et al. 2020). However, in developing countries, there is limited empirical evidence about the benefits of social network benefits in climate change adaptation (Dapilah, Nielsen, and Friis 2020).

Sharing of labour and income across households, borrowing funds from family or neighbours, getting help in the form of food, shelter, and labour to affected families, prayer and community fundraising are some of the social relation activities reported (Gentle, Thwaites, and Race 2018; Funk et al. 2019; Kluger et al. 2020). Accordingly, social networks can be less effective, especially during severe climate shocks such as droughts and floods, where most households within the area are affected simultaneously and unable to assist each other (Son and Kingsbury 2020). More so, threats emanating from climate change will force rural communities to temporarily or permanently migrate, thus depriving social relations within the rural households.

In terms of food and water security to climate change, rural communities employ different strategies to reduce food insecurity by changing diet, reducing the number of meals, and consuming less food per day. Most of the articles in Africa and Asia maintained that altering food intake is a prominent adaptive measure to climate-induced food shortages (Antwi-agyei et al. 2018; Aryal et al. 2020; Son and Kingsbury 2020), despite its negative impact on the health of the rural communities. assert that crucial assessments regarding this coping strategy to food insecurity are required, since altering food intake has consequences on affected rural households' health well-being. Also, the analysis revealed different food preservation methods employed by rural communities. For example, during droughts in Papua New Guinea, rural communities dug pits and put crops such as sweet potato, banana, sugarcane, and green vegetables on the ground, where the environment is much cooler to ensure that the food stays fresh much longer (Gwahirisa, Pamphilon, and Mikhailovich 2017). Based on the analysis, only two studies from Africa reported cultural activities such as prayer and traditional rituals related to climate change adaptation (Aniah, Kaunza-nu-dem, and Ayembilla 2019; Mabuku et al. 2019). For example, about 60% of the sampled rural communities in Mwandia District, Zambia, observed prayer as a long-term adaptation strategy against floods (Mabuku et al. 2019). Another example from Bongo District, Ghana, where rural communities took part in traditional cultural practices as a norm to reverse climate calamities like droughts (Aniah, Kaunza-nu-dem, and Ayembilla 2019).

#### *2.6.4 Top-down approaches to Climate change Adaptations*

Three studies that were conducted in Africa and Asia, two in South and North America and one in Australasia reported on importance of institutions in shaping climate change adaptation strategies. This serves as evidence showing that there is a limited number of studies reporting on top-down approaches to climate change adaptation through involvement of government and other formal institutions. The assistance from the government and Non-Governmental

Organisations is reported through the provision of government relief funds, food aid, obtaining government compensation for crop damages, technical assistance, resettlement and building temporary or permanent houses (Kolawole et al. 2016; Oviedo et al. 2016; Hermans and Garbe 2019; Son and Kingsbury 2020). However, the government's support has created a dependence syndrome on social welfare and reduced self-reliance on rural communities (Son and Kingsbury 2020). Little is known about how local knowledge is rooted within the external support in terms of policies, institutions, resources, and technology (Gentle, Thwaites and Race, 2018). A study conducted in Uttar Pradesh, India, found that institutional policies and recommendations prescribed for adapting to climatic stressors were hardly suited to the rural communities' needs (Singh et al. 2019). A similar report was made in Verde Valley, Arizona, highlighted that though the rural communities received support from the local non-profit organizations, there were differences between the organization's programmes and local communities' needs (Douglass-gallagher and Stuart 2019). Cases of maladaptation can be attributed to a lack of understanding of local socio-economic and cultural contexts by government officials (Son and Kingsbury 2020). Therefore, governments and administrative agencies should consider the rural communities' necessities to develop effective and sustainable rural livelihood adaptations.

## **2.7 Discussion**

This paper seeks to identify the common traits and differences between databases on climate change and variability and the effects of these phenomena on rural livelihoods. It adopted the PRISMA model to assess literature on the impact of climate change on rural livelihoods. The analysis of the reviewed literature revealed some findings that can help understand the severity of climate change and the vulnerability of rural communities to its impacts, including extreme events. The differences in what has been reported about climate change impacts and how rural communities have responded to it indicates the need for context-specific rural livelihood policy-making processes for climate change adaptations. Although there are common global traits regarding the nexus between climate change and rural livelihoods there are also glaring differences between regions, and between countries in specific regions. Such a scenarios make it difficult for the formulation of universal adaptation strategies and requires more localised approaches with studies like this study.

One main common observation that emerged across the literature was that climate change and variability manifestations are not uniform, but diverse and context specific. This is because across different geographic locations, specific climate change implications are characterized

by local climate characteristics. For illustration, there are more drought threats to rural livelihoods in the arid and semi-arid regions of North-Western China and Ethiopia (Chen et al. 2018; Tolera and Senbeta 2020), than in coastal areas such as Bangladesh, Fiji and South Carolina where risks of sea-level rise, floods and cyclones are high (Bhattachan et al. 2018; Hossain et al. 2018; Shahzad et al. 2019). These differences can be attributed to prevailing environmental, political, cultural and socio-economic conditions prevailing in regions and within countries (Steele et al. 2018; Chhogyel et al. 2020). Therefore, it is critical to note that the effects of climate change and variability on rural livelihoods vary according to the characteristics of the region.

This view is consistent with most studies. The dissimilarities in context are embedded in cultural pluralism and manifested through norms, gender roles, inheritance patterns, land tenure and land-use patterns. Consequently, understanding the impact of climate change on rural livelihoods requires a combination of interventions rather than focusing on individual drivers, in this case, climate change. Also, rural communities will not effectively abate the effects of climate change and variability on their livelihoods if the indirect socio-economic systems are excluded from their adaptation measures.

Another critical finding of this paper is there is consistency in literature supporting the view that adaptation strategies introduced by the rural communities across the continents are autonomous. A considerable amount of literature has acknowledged the importance of IKS inadaptation to climate change. Also, most adaptation strategies implemented are a response to rural livelihood shifts induced by climate variability impacts (short-term changes) rather than climate change (long-term changes), which leads to maladaptation. Poor communities from developing countries are the most vulnerable because they have limited relations with formal institutions, lack resources to effectively adapt to climatic and non-climatic changes. Therefore, it is crucial for government to effectively implement sustainable short-term coping and long-term adaptation strategies to halt maladaptation.

The analysis of the reviewed literature also revealed that most adaptation policies to climatic change and variability are still mainly based on top-down approaches and lack sufficient incorporation of IKS from rural communities. Hence it is imperative to secure bottom-up approaches in the era of varying climate change to ensure the sustainability of local communities' measures to climate change. As such, any input and support from external and internal institutions might influence the decisions that rural communities make, and the

resultant adaptation strategies are unlikely to succeed. Bottom-up initiatives consider local concerns and current demands to address any environmental issues. Focus groups, questionnaires, and participatory methods are some of the methods used to provide contextualized insights about climate change implications to develop the bottom-up approaches. While top-down approaches to climate change focus on projected changes in climate through projections or modelled predictions, planned adaptations implemented by local governments or NGOs are mostly based on present and future climate implications, while local communities implement them based on past and present impacts and less consideration of future impacts. The analysis shows that the local communities' bottom-up approaches are more based on the immediate fulfilment of livelihood strategies in addressing the current impacts. The review, however, finds that top-down methods to climate change adaptation have failed to achieve local sustainable development. This could be due to stakeholders' failure to incorporate local engagement as well as socio-cultural factors such as social learning and knowledge exchange. In this regard, the review has shown different socio-cultural activities that are considered for adoption by the local communities which stakeholders might have found them invalid.

Most studies have highlighted the lack of involvement of rural communities in adaptation planning and development, which has resulted in conflicts and maladaptation, as those adaptation policies are often at variance with the decisions and needs of rural communities. Integrating both approaches to managing climate change impacts by both institutions and local people remains unfulfilled. Combining the two approaches could yield significant adaptive measures that are superior to what either approach could achieve separately. There is importance in considering the complete participation of local communities in top-down efforts. There may be times when stakeholders are willing to help, but they are hampered by a lack of complete cooperation from local populations. However, the attitude of local populations toward participation has not been thoroughly investigated.

## **2.8 Conclusion**

Rural livelihoods are complex and multifaceted, hence the effects of climate change implications on rural livelihoods are also complicated. The divergences found across literature are interlinked with geographical, environmental, social, economic, institutional, and political factors. Therefore, adaptation to climate change is context and location specific. Thus, it is somehow essential to understand how rural livelihoods respond to context specific climate change and variability across the globe and how best government plans, policies, and strategies

have to be designed and implemented based on relevant context. Based on the analysis, we conclude that these differences are attributed to exposure to various climate change conditions and non-climatic factors, namely social, economic, cultural, and political factors. We also recommend that government and local organizations should be jointly involved in developing policies that contextualize and suit the needs of rural communities and enable these communities to develop autonomous adaptation measures that will achieve their own long-term benefits. Above all, due to non-homogeneity of climatic change and the environment in which it takes place and its effects on rural livelihoods, policies must be flexible to suit the different needs of specific rural households.

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### **Author Contributions**

Conceptualization, G.M.; methodology, L.M and G.M.; validation, G.M.; formal analysis, L.M.; data curation, L.M.; writing—original draft preparation, L.M.; writing—review and editing, G.M.; supervision, G.M.; project administration, G.M.; funding acquisition, G.M.

**Conflict of Interest:** The authors declare no conflict of interest.

## CHAPTER 3: EXAMINING TEMPERATURE AND PRECIPITATION TRENDS AND HOUSEHOLD PERCEPTIONS OF CLIMATE CHANGE IN THE EASTERN FREE STATE REGION OF SOUTH AFRICA

### 3.1 Brief chapter synopsis

The chapter is based on an article which has been submitted to a journal for publication as

Msimanga, L.\*, & Mukwada, G. (2022). Examining temperature and precipitation trends and household perceptions of climate change in the Eastern Free State Region of South Africa. *Journal of Mountain Science*.

### 3.2 Abstract

This study examines trends of minimum and maximum temperatures, and precipitation, in the Eastern Free State Region of South Africa. Climate Explorer was used to obtain yearly minimum and maximum temperatures, and average monthly precipitation data for the period 1960 to 2019. The Mann Kendall (MK) Test and Sen's estimate were employed to determine the nature of the trends and their significance, while a questionnaire survey was done to determine the perceptions of local communities about climate trends in the region. The Standardized Precipitation Index (SPI) was calculated for the January to March (JFM) and October to December (OND) sub seasons and for the ONDJFM in R-Studio 1.1.1717 software using monthly rainfall data for the 1961 to 2019 period. The results show a significant rise in the long-term annual mean maximum and mean minimum temperatures, which have increased by  $0.034^{\circ}\text{C}/\text{annum}$  and  $0.011^{\circ}\text{C}/\text{annum}$ , respectively. Consistent with the perceptions of surveyed households, the results of the analysis revealed an increase in maximum temperatures, a decline in precipitation, and consecutive dry years during this period. Most respondents cited an increase in  $T_{\text{max}}$ , a decrease in  $T_{\text{min}}$ , changes in precipitation patterns during the OND and JFM seasons and increasing drought episodes. The study concludes that if appropriate adaptation strategies are not adopted these changes may contribute to water scarcity and food insecurity in the area, with negative consequences for the livelihoods of local households in the region.

**Keywords:** Drought; Mann-Kendal trend test; Standardized Precipitation Index; Eastern Free State Region; Rural livelihoods; Perceptions.

### 3.3 Introduction

Climate change alters the intensity, frequency, spatial extent, duration, and incidence of severe climatic and meteorological phenomena, resulting in previously unprecedented extreme

climatic occurrences (Costa et al. 2020). Evaporation, transpiration, and changes in water demand are all influenced by temperature, which has a substantial impact on both water supply and food security (Mohamed and Mukwada 2019). As a result, combating household food insecurity and impoverishment requires a comprehensive understanding of climate indicators such as temperature, rainfall, and extreme occurrences such as floods and droughts.

Climate change impacts differ across spatial scales within mountain ecosystems (Sharma, Batish, and Uniyal 2020). Mountainous landscapes are assumed to be early indicators of climate change and fluctuation. The Drakensberg Mountains, which comprise the majority of the eastern parts of the Free State Province are an example of a high mountain range in South Africa (Mbiriri, Mukwada, and Manatsa 2019; Mohammed and Mukwada 2019). The Free State Province has a complicated terrain as well as a highly varied climate (Mbiriri, Mukwada, and Manatsa 2018), and its mountainous eastern region is mainly sensitive to climate change. Increasing temperatures and a high intensity of (Poudyal, Dawadi, and Devkota 2019) drought, resulting from excessive evapotranspiration will reduce the accessibility of water sources for crop production (Abbasian, Najafi, and Abrishamchi 2021), putting the livelihoods and economies of these local communities in the region at risk.

Studying climate change in mountains necessitates a high density of meteorological data due to the considerable microclimatic variance (Spies 2020). However, because mountains are inaccessible, there is a shortage of studies regarding how they are impacted by climate change (Ullah et al. 2018; Mohamed and Mukwada 2019). It is critical to document local people's views on climate variation and incorporate them in planning and development of policies (Sharma, Batish, and Uniyal 2020). As a result, an increasing number of studies have considered using mountain communities' perceptions in surveys and interviews to explore local climatic trends. Examples include studies in Asia (Poudyal, Dawadi and Devkota, 2019; Sun et al. 2015; Mijiddorj et al. 2020; Huang et al. 2019) and Africa (Mkonda and He 2017; Kahsay et al. 2019). However, none of the studies have examined the variability of household perceptions on climate change in diverse altitudinal regions. Schneiderbauer et al. (2021) indicate that there have been few studies that have assessed risk perceptions in communities in the same mountain range, or communities in different mountainous regions, or communities in different elevation areas. There is a dearth of literature on Southern African mountains (Abubakar et al. 2021; Mukwada, 2022; Takong and Abiodun, 2023), particularly the Drakensberg Mountains of the Eastern Free State Region of South Africa. Limited studies have

been done to examine the views of local communities on climatic trends across different elevation zones. This study, therefore, seeks to fill this gap.

According to Pandey et al. (2018) local communities retain in-depth knowledge of their surroundings developed from individual observation, experience and culture, involving shared experiences among others. Nnko et al. (2021) state that personal experiences from repeated climatic events build peoples' perceptions and influence the adaptation actions that they might adopt. On the contrary, Cherinet and Mekonnen (2020) state that perceived environmental changes may not represent actual events, due to a lack of understanding of climatic events or patterns.

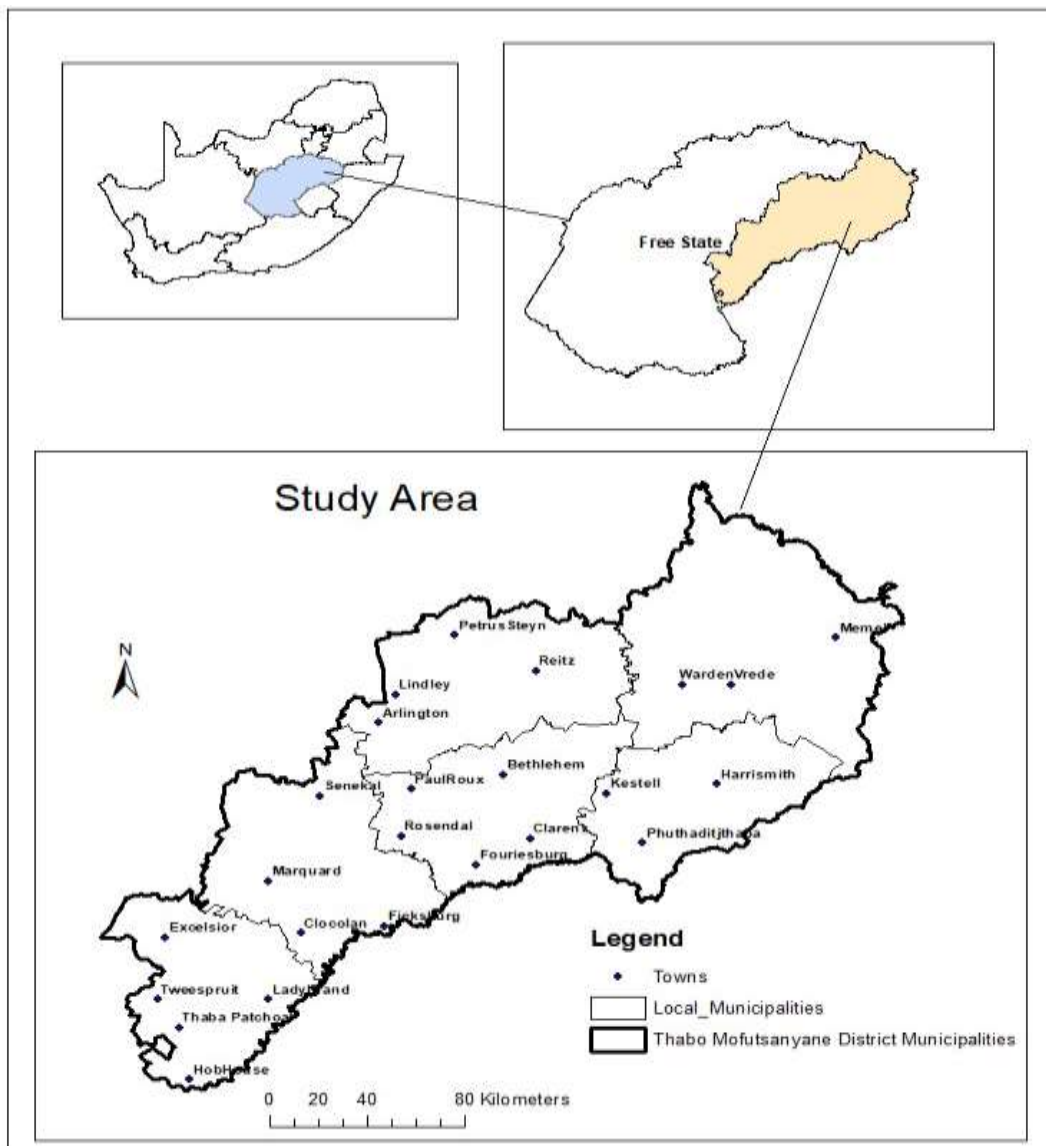
Studies that incorporate household perceptions and climate data have been found to be an important step towards adopting local-specific and appropriate adaptation options (Guodaar, Bardsley, and Suh 2021; Imran, Shrestha, and Datta 2020). Therefore, in this study, incorporating household perceptions in climate change studies will assist our understanding of how household perceptions are consistent with scientific information. Such an approach will enhance effective use of local knowledge in developing sustainable climatic change adaptation measures. However, there are very few studies that have incorporated household perceptions into climate change studies in the mountainous areas of the EFSR.

Agriculture is the key source of livelihoods for the greater part of the EFSR communities. According to Poudyal, Dawadi, and Devkota (2019), communities whose livelihoods are based on agricultural activities have a better perception of climate change impacts because the climate has a direct impact on their productivity and yields. It is, therefore, critical to understand how local communities in the EFSR perceive climate variability and its implications on their livelihoods, as well as whether their perceptions are compatible with climatic data. This paper is of critical importance in that it provides climate data that could be crucial in assisting local households in deciding the appropriate agricultural and socioeconomic management strategies to deal with extreme environmental conditions resulting from climate change. Thus, the aim of this paper is to: (1) explore the spatial variability and temporal trends of maximum and minimum temperatures and precipitation in the EFSR for the period between 1960 and 2019, and (2) assess the perceptions of local communities in the region to determine the compatibility of those perceptions with the scientific evidence derived from the climate data and the degree to which they can be used to develop sustainable climate change adaptation strategies.

### 3.4 Materials and methods

#### 3.4.1 Description of the Study Area

The study area is located in the Thabo Mofutsanyane District (TMD), in the EFSR (Figure 3.1). The EFSR mainly comprises the TMD and it is bounded by Drakensberg and Maluti Mountains separating it from, KwaZulu Natal and Eastern Cape provinces and Lesotho.



**Figure 3.1** Map of South Africa, Free State Province and Thabo Mofutsanyane District (TMD), showing the towns across the Local Municipalities.

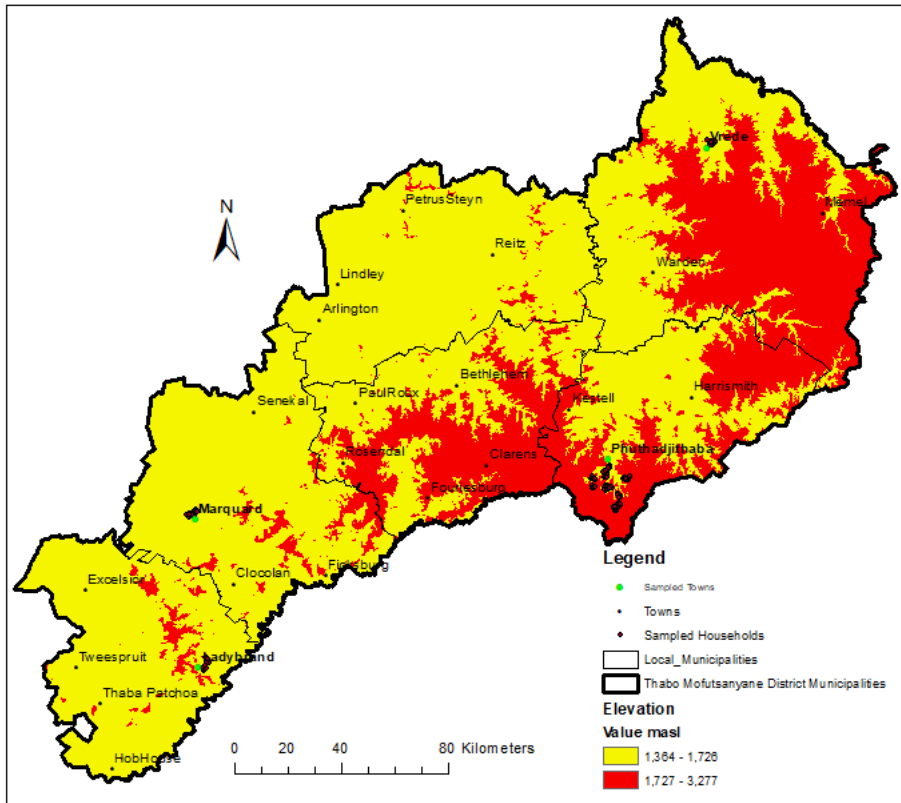
The district is within the Afromontane region, and located between 27°03' and 29°08' S and between 119°37' and 121°26' E. The TMD makes up almost a third of the Free State Province's geographical area, with an area of 33 269km<sup>2</sup>. The district comprises six local municipalities: Setsoto, Dihlabeng, Nketoana, Maluti-a-Phofung), Phumelela and Mantsopa. The topography

of the ESFR is mountainous and rugged, with relatively variable elevation ranging between approximately 1500 and 3000m above sea level (Moeletsi and Walker 2012). The TMD is a representative rural district, and it has 24 small towns that serve the surrounding rural communities.

Moeletsi and Walker (2013) state that the region receives precipitation that ranges between 500-600 mm, more rainfall than the rest of the Free State Province (Mbiriri, Mukwada, and Manatsa 2018), making it more appropriate for rainfed crop farming compared to the rest of the province (Moeletsi and Walker 2013). In the EFSSR, the mean maximum temperatures range between 20<sup>0</sup>C and 22<sup>0</sup>C, while minimum temperatures range between 5<sup>0</sup>C and -1<sup>0</sup>C (Dube et al. 2019). The risk of frost varies significantly in the region due to the contrasting topography and geographical aspect (Moeletsi, Tongwane, and Tsubo 2016).

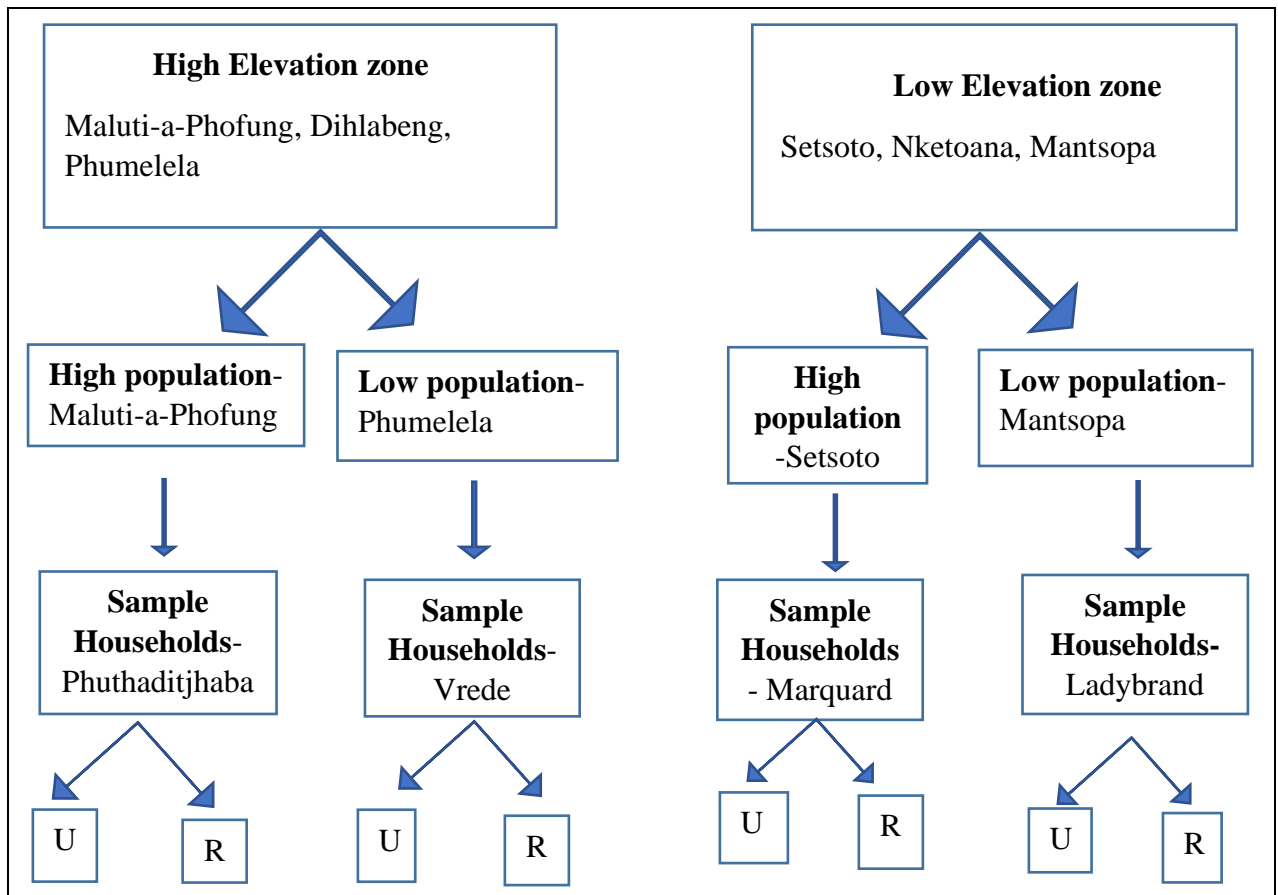
#### *3.4.2 Sampling Design*

As noted above, the district comprises six local municipalities. Multi-stage sampling was employed to select four of the local municipalities, namely Setsoto, Maluti-a-Phofung, Phumelela and Mantsopa. The first stage involved stratified sampling, whereby the six local municipalities were divided into two altitudinal zones based on elevation, where the high elevation zone ranges from 1727 to 3277 metres above sea level (masl). These were the Maluti-a-Phofung, Phumelela and Dihlabeng municipalities. The low elevation zone ranges from 1364 to 1726 masl, and comprised the Setsoto, Mantsopa and Nketoana municipalities (Figure 3.2).



**Figure 3.2** Relief of the EFSR, and Sampled Towns showing the Sampled households.

According to the Community Survey that was conducted in 2016, Maluti-a-Phofung has a population size of 353 433, followed by Dihlabeng 140 044, Setsoto 117 361, Nketoana 64 894, Mantsopa 53 525 and Phumelela 50 054 (<https://wazimap.co.za/profiles/district-DC19-thabo-mofutsanyane/>). The second stage involved selecting the study sites according to population size. Two municipalities were selected in each zone, one with the highest population and the other with the lowest. Thus, sampled households were chosen based on population size in order to capture a representative sample of the actual situation on the ground. The respective municipalities that were selected were Maluti-a-Phofung and Phumelela for the higher elevation zone and the Setsoto and Mantsopa municipalities for the lower elevation zone. The third stage of sampling involved grouping the households according to settlement type (rural and urban sections). The households that were sampled in the rural and urban sections of the sampled settlements were randomly chosen for inclusion in the study. Figure 3.3 presents the criteria for selecting sample households.



**Figure 3.3** Criteria for selecting sample households (U- Urban areas, R- Rural areas)

### 3.4.3 Data Sets and methods

#### **Primary Data collection**

This study relied mainly on primary data sources, including raw climate data which were used to compute climate indices to determine nature of temperature and precipitation trends in the study area. Data on climate change perceptions, and local adaptation measures were collected via a household survey. Household-level perceptions on climate change and its impacts on livelihoods and adaptation strategies were explored using a semi-structured questionnaire (Appendix 4). A pilot survey was carried out prior to the survey to test the suitability of the questionnaire. Fifteen respondents participated in the pilot survey. The sample size was calculated using the Yamane formula (1967). The formula used to calculate sample size was derived from Yamane (1967) and is as follows:

$$n = N / 1 + N(e)^2$$

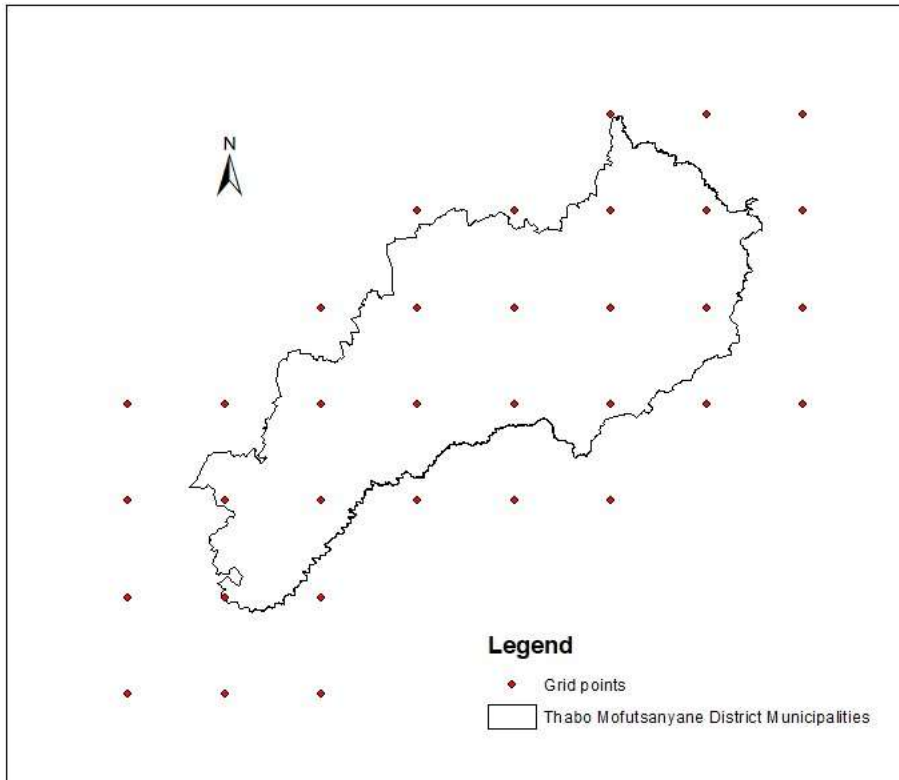
where  $n$  represents the sample size and  $N$  is the population size (179508 households). The sampling was done at 95% confidence level, with a level of precision ( $e$ ) of  $\pm 8\%$ . Therefore, the sample size was 400 for this study. The households that were sampled in the rural and urban sections of the sampled settlements were randomly chosen for inclusion in the study.

**Table 3.1** Sample size

<b>Elevation Zone</b>	<b>Local Municipalities in the Zone</b>	<b>Population size</b>	<b>Number of Households</b>	<b>Sample size</b>
High Elevation	Phumelela	50 054	14 586	33
	Maluti-a-Phofung	353 453	110 725	247
Low Elevation	Setsoto	117 361	37 246	82
	Mantsopa	53 525	16 951	38
<b>Total</b>		<b>574 393</b>	<b>179508</b>	<b>400</b>

### **Climate Indices**

Minimum and maximum monthly temperature data for the study area were taken from Climate Explorer (available from <https://climexp.knmi.nl>) for the 1960–2019 period. The data were acquired from the Climate Research Unit Time-Series (CRU-TS4.1) at a 0.5 x 0.5 resolution. A total of 34 grid points inside the borders of the Eastern Free State Region and the ones in the surrounding area were included for analysis (Figure 3.4). Annual and seasonal January-March- (JFM) and October-December- (OND) and subseason October-March-(ONDJFM) average maximum ( $T_{max}$ ) and minimum ( $T_{min}$ ) temperatures, and average total precipitation were used in this study.



**Figure 3.4** Location of the Grid points

For this study, the Standardized Precipitation Index (SPI) by Mckee, Doesken, and Kleist (1993) was used to determine the frequency of drought occurrence based on average precipitation received during the JFM sub-season and ONDJFM season. The SPI is suitable for drought monitoring and assessment of monthly and above scales relative to local climatic conditions. Only the precipitation data is required for SPI calculation. SPIs were calculated for each grid point from rainfall data using RStudio 1.4.1717 statistical software. SPIs calculated at short-term scales are a more suitable estimate of seasonal rainfall that has a significant impact on soil moisture condition, crop production and vegetation growth (Mallya et al. 2013; Mbiriri, Mukwada, and Manatsa 2019).

The SPI values were used to determine both drought duration and intensity. The intensity of drought is determined by the SPI value applied to the classification in **Table 3.2**.

**Table 3.2** Categorization of dryness/wetness. Adapted from (Agnew 2000) and modified by (Manatsa et al. 2010)

SPI Value occurrence	% Occurrence	Nominal SPI class
>1.645	≤5	Extremely wet
1.644 to 1.282	6-10	Severely wet
0.842 to 1.281	11-20	Moderately wet
0.524 to 0.841	21-33	Slightly wet
-0.523 to 0.523	34-50	Normal
-0.841 to 0.524	21-33	Slight drought
-1.281 to -0.842	11-20	Moderate drought
-1.644 to -1.282	6-10	Severe drought
<-1.645	≤5	Extreme drought

#### 3.4.4 Data Analysis

##### *Analysis of Primary Data*

Statistical analysis was done using Microsoft Excel 2016 and SPSS (Version 17.0). The data for the study were recorded, processed, and analysed statistically for descriptive statistics (frequency and percentage).

##### *Trend analysis of climate data*

The study used different statistical approaches to assess the spatiotemporal changes in  $T_{max}$ ,  $T_{min}$ , precipitation and drought extremes over the Eastern Free State. The non-parametric Mann Kendall (M.K) test (Mann 1945; Kendall 1975) was used to determine the presence of a trend in mean maximum and minimum temperatures and precipitation indices, whereas the Sen's Slope (SS) estimator was employed to calculate the magnitude of the trend in the selected indices. In detecting the trend, a hypothesis was set as follows: null hypothesis ( $H_0$ ) signified no trend, and the alternative hypothesis ( $H_1$ ) indicated the presence of a trend. According to (Sharma, Batish, and Uniyal 2020), several scholars have included the Mann-Kendell test to evaluate trends in climate time series data. For the reason that the MK test does not need the

normality of data, it depends on the median than the mean, (Alyousifi et al. 2021). Lastly when using the non-parametric analysis, no preceding transformation of data is involved. Despite its advantages and recognition, Mohamed and Mukwada (2019) state that the M.K test has not yet been extensively used in evaluating temperature trends. However, temperature is the primary indicator that influences other climate-related variables (Mohamed and Mukwada 2019). The XLSTAT statistical add-in for Microsoft Excel 2021 was used to perform the test. More details on the procedures and equations for the Mann–Kendall test can be found in Asfaw et al. (2018) and Worku et al. (2019).

The nonparametric Sen’s slope estimator proposed by Sen (1968) was used to determine the magnitude of trends, which assumes that the trend is linear. When a linear trend exists in a time series, then the slope ( $Q_i$ ) of a time series can be expressed as follows (da Silva et al. 2020):

$$Q_i = \frac{x_j - x_k}{j - k} \quad i = 1, 2, 3, \dots, N$$

where  $X$  represents the differences of annual values, and  $x_j$  and  $x_k$  denote values in the time series data at  $j$  and  $k$ , respectively, where  $j > k$ .

The SPI drought indices were used to analyse drought frequencies. To identify abrupt changes or shifts in the temporal trend of selected indices, the study used the Sequential Regime Shift Detection (SRSD) method (Rodionov 2004). Spatiotemporal analysis of the SPI values was undertaken to determine trends in precipitation through time and geographic space. All maps were using Inverse Distance Weighting (IDW) in ArcMap V 10.7.1 for spatial interpolation techniques. As part of trend analysis, the SRSD method was used to detect any significant changes in the climate indices in the study. The selected statistical techniques have been widely used by various researchers in their climatological and hydrological studies over different climatic regions of the world (Mentzafou, Wagner, and Dimitriou 2018; Hormozi, Borna, and Zohourian 2021; Wang et al. 2020; Mohamed and Mukwada 2019).

### **3.5 Results and Discussion**

#### *3.5.1 Household Perceptions on Climate Change in the Eastern Free State Region*

From the survey data, the local respondents acknowledged the changes in the rainfall and temperature patterns and events of natural disasters. The frequency and percentages of

respondents' responds to climate change perceptions across the sampled municipalities are shown in Table 3.3. As shown in Table 3.3, the findings indicate that more than 50% of the respondents in both elevation zones reported a decrease in  $T_{min}$  and an increase in  $T_{max}$ . In the high elevation zone (Phuthadjithaba and Vrede), about half of the respondents reported an increase in precipitation. However, in the low elevation zone (Ladybrand and Marquard), about 53 % of the households in Marquard reported an increase in precipitation compared to the 68.4 % in Ladybrand who perceived the opposite.

**Table 3.3** Households' perceptions of climate change

		LOW ELEVATION ZONE		HIGH ELEVATION ZONE	
		Ladybrand (38)	Marquard (81)	Vrede (34)	Phuthaditjhaba (247)
Maximum Temperatures	Increase	34 (89.4%)	70 (86.4%)	25 (74%)	171 (69%)
	Decrease	2 (5.3%)	6 (7.4%)	2 (6%)	45 (18%)
	No change	2 (5.3%)	5 (6.2%)	7 (20%)	31 (13%)
Minimum Temperatures	Increase	11 (30%)	17 (21%)	7 (20%)	42 (17%)
	Decrease	24 (63%)	58 (71.6%)	19 (56%)	137 (55%)
	No change	3 (7%)	6 (7.4%)	8 (24%)	68 (27%)
Precipitation	Increase	7 (18.4%)	43 (53%)	11 (32%)	101 (41%)
	Decrease	26 (68.4%)	31 (38%)	17 (50%)	127 (51%)
	No change	5 (13.2%)	7 (9%)	6 (18%)	19 (8%)

**N=400**

Climate data (Figure 3.11) showed that precipitation was decreasing and there were longer dry periods, which was reflected in respondents' views of decreased rainfall. The household's impressions are likely to be biased toward the second half of the study period and having a climate record supports the research. Most of the households interviewed said that the climate has changed in the last 5–15 years, resulting in climate change implications on their livelihood activities.

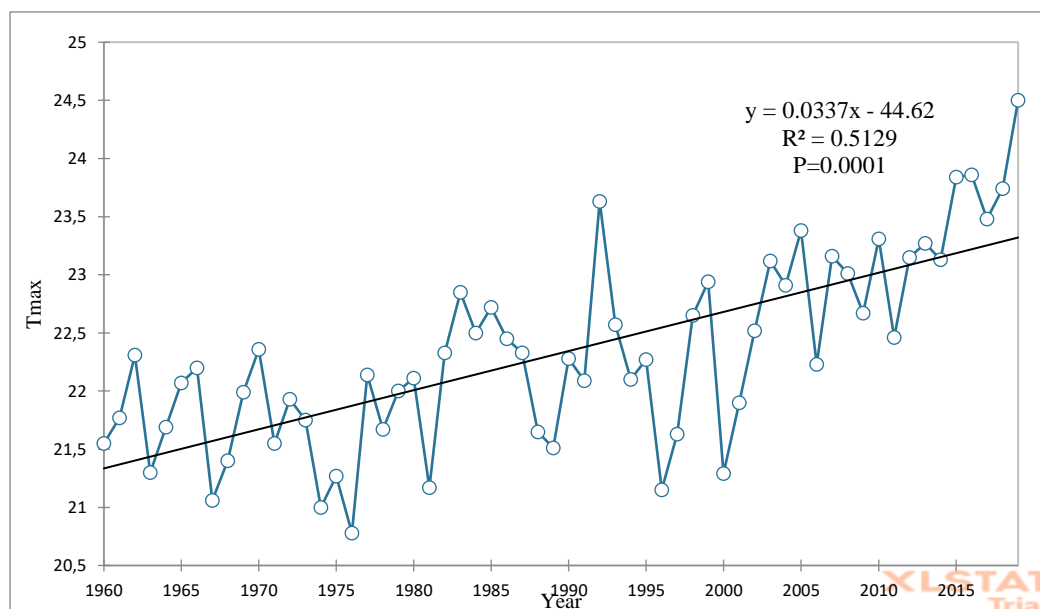
### 3.5.2 Spatiotemporal variability of climate in the Eastern Free State Region

The Mann–Kendall test, a non-parametric test and Sen’s slope estimator method were applied on average annual maximum-minimum temperatures and precipitation for the 1960–2019 period. The shifting point detection and RSI for temperatures (minimum and maximum), precipitation and SPIs were well-defined by the SRSD method. Descriptive statistics of the yearly average of minimum temperatures and maximum temperatures and precipitation in the Eastern Free State region are provided in Tables 3.4, 3.5 and 3.6, respectively in sub-section 3.5.2.1.

#### 3.5.2.1 Temporal variability of temperature and related trends

##### *Average Maximum Temperature*

Figures 3.5, 3.6, and 3.9 present the results of the average Maximum Temperature in the EFSR. The results show that a significant change has occurred in the average Maximum Temperature ( $T_{max}$ ) over the past 59 years. The mean annual  $T_{max}$  of the area during the studied period was 22.3 °C, with a standard deviation of 0.821 °C. The minimum  $T_{max}$  recorded was 20.8 °C and the maximum ever recorded  $T_{max}$  was 24.5 °C.



**Figure 2.5** Annual average maximum temperature for the period 1960–2019.

##### *Mann Kendall Test*

The M.K results for average annual maximum temperature are shown below. The p-value shown in Table 3.4 is lower than the significance level (0.05). One would therefore accept the null hypothesis ( $H_1$ ) and reject the ( $H_0$ ). This suggests that the annual trend of maximum temperatures had increased over the years. Sen’s slope of mean maximum temperature was 0.034  $^{\circ}\text{C}/\text{annum}$ . The maximum temperature had an increasing trend (0.034), according to the Sen’s slope results.

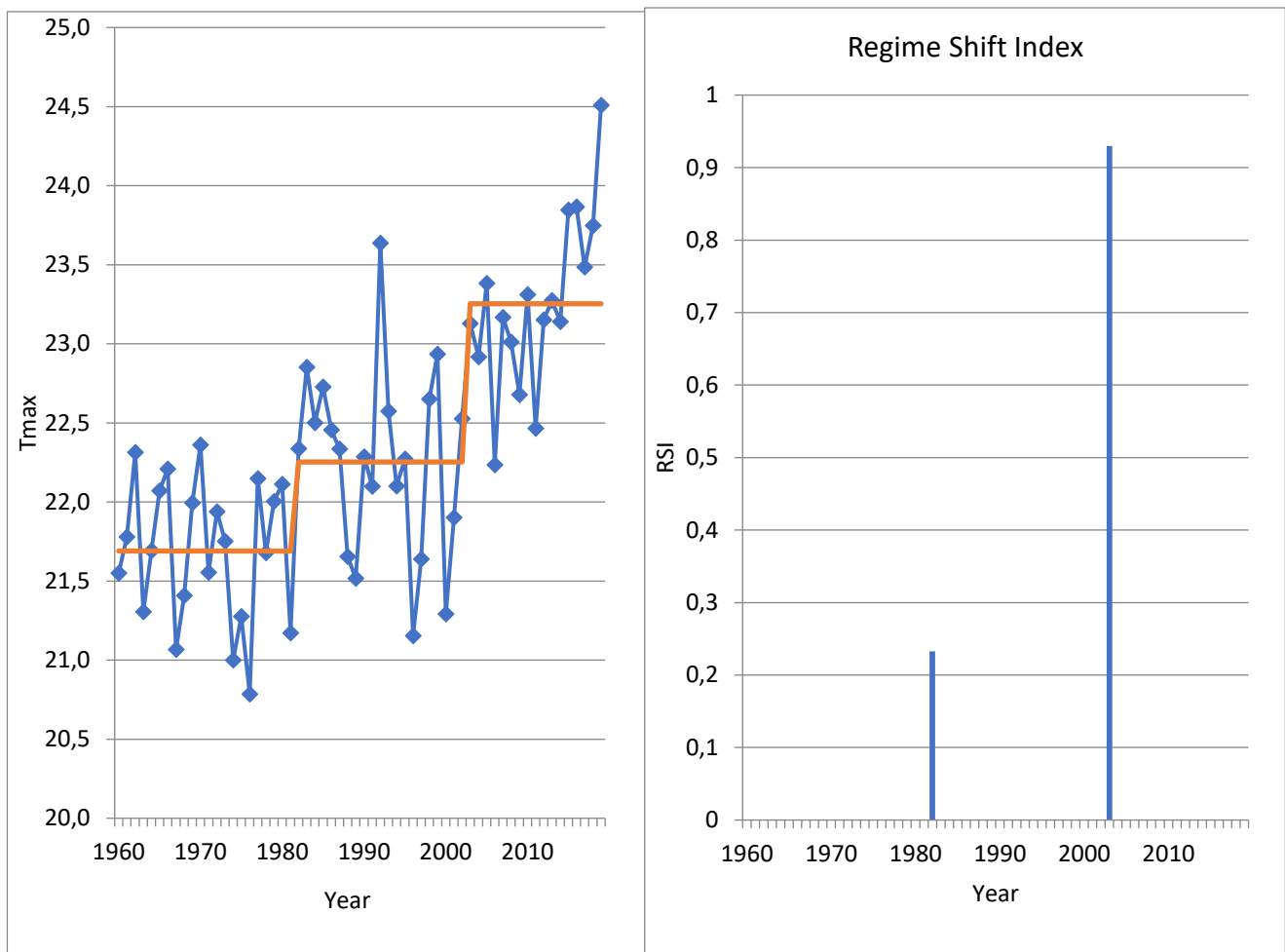
**Table 3.4** M. K test results of annual average maximum temperature.

<b>Statistic Description</b>	<b>Temperature Data</b>
Observations	60
M.K Statistic (S)	920.0
Kendall’s Tau	0.520
P value	<0.0001
Alpha	0.05
Sen’s slope	0.034
Test interpretation	Accept $H_1$

The study findings are aligned with those of recent studies by Mohamed and Mukwada 2019 and Abubakar, Scholes, and Newete 2020, which found a significant increase in annual maximum temperatures in Maloti-Drakensberg Region and Setsoto Municipality in the Free State Province, South Africa. Local communities in the study area have experienced significant changes in summer temperatures. This is in line with findings from previous studies that have highlighted an increase in temperatures over the study period (Kaganzi et al. 2021; Olana Jawo et al. 2023).

***Change Point Detection***

The findings from the SRSD method on the average maximum temperatures (Figure 3.6) revealed that  $T_{\text{max}}$  variables had an abrupt change.

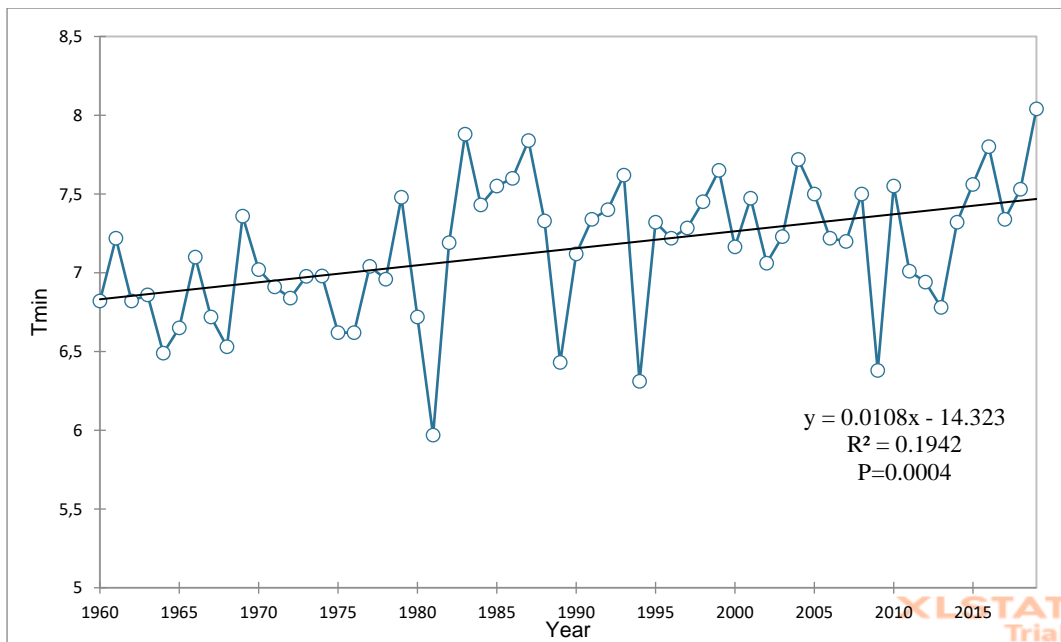


**Figure 3.6** Shifts in the mean for maximum temperature, 1960-2019. Target  $p=0.05$ , cutoff length=10, turning point=2

The results from the RSDS indicated that there was rapid warming in the region as evidence reveals two incidents of abrupt temperature shifts. An abrupt increase in  $T_{\max}$  was detected in 1982, with RSI of 0.2326 and another shift in 2003 with RSI of 0.9296. The regime shift analysis appears to show that the local communities in the region are experiencing hot environment. As a result, such rapid changes have a negative impact on resilience and the development of coping and adaptation mechanisms, particularly in rural areas where autonomous adaptations are the norm. Furthermore, such strategies are considered ineffective due to abrupt adjustments **that catch communities off guard** and leave them exposed to the consequences of these shifts.

### *Average Minimum Temperature*

Figure 3.7 below shows the average annual minimum temperature from 1960-2019. During the period under study, the mean minimum temperature in the region was 7.2 °C, with a standard deviation of 0.43 °C. The minimum and maximum  $T_{min}$  values recorded were 6 °C and 8 °C.



**Figure 3.7** Average annual minimum temperature from 1960–2019.

### ***Mann Kendall Test***

The same applies for minimum temperatures, which are statistically significant ( $p = 0.05$ ) as shown in Table 3.5. The results show that the p-value is less than the significance level (0.05). One accepts the alternative hypothesis ( $H_1$ ) and rejects the null hypothesis ( $H_0$ ).

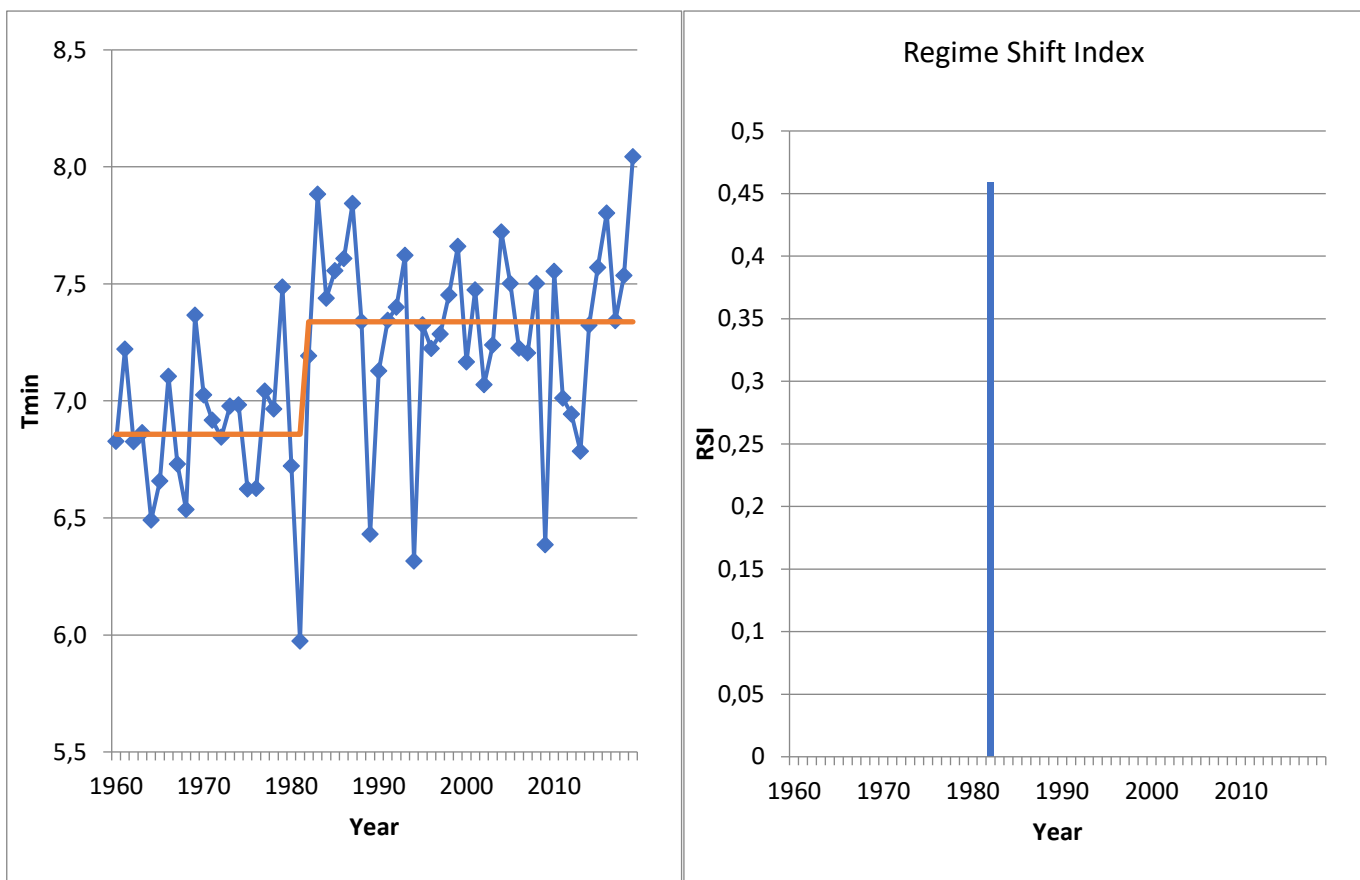
**Table 3.5** M. K test results of annual average minimum temperature.

<b>Statistic Description</b>	<b>Temperature Data</b>
Observations	60
M.K Statistic (S)	568.00
Kendall's Tau	0.322
P value (2-way test)	0.000
Alpha	0.05
Sen's slope	0.011
Test interpretation	Accept $H_1$

The minimum temperatures have increased between 1960 and 2019. Sen's slope of yearly mean minimum temperature was  $0.011 \text{ }^{\circ}\text{C}/\text{annum}$ . The findings concur with some of the studies by Almeida et al. (2016) and Asfaw et al. (2017), where the trend analysis result of minimum temperature showed a statistically significant increase.

### *Change Point Detection*

With respect to the regime shift in the mean for minimum temperatures shown in Figure 3.8, there was one shift that occurred in 1982 with RSI value of 0.4586. The results imply that the winter seasons in the region have become warmer. The regime shift analysis appears to show an increase in shifts in  $T_{\max}$  and  $T_{\min}$  that occurred in corresponding year.

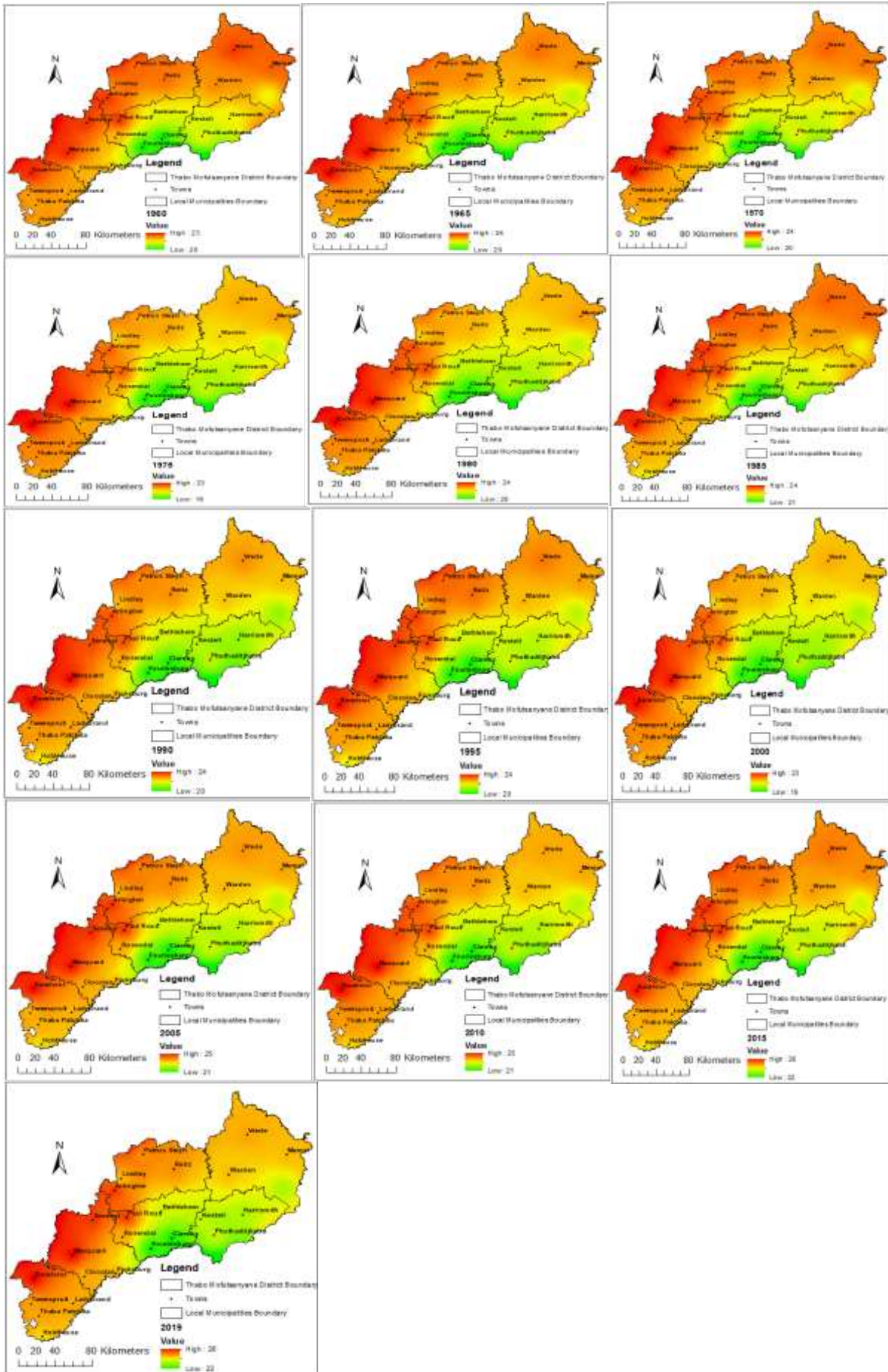


**Figure 3.8** Shifts in the mean for minimum temperature, 1960-2019. Target  $p=0.05$ , cutoff length=10, turning point=2

### **3.5.2.2 Spatial variability of temperatures in the Eastern Free State Region**

#### *Spatial analysis of maximum temperatures in the Eastern Free State Region.*

Figure 3.9 shows the analysis of the temporal and spatial variability of  $T_{\max}$  values in the region from 1960 to 2019. The results (Figure 3.9) indicate that the maximum temperatures in the EFSR have increased, with the average maximum temperature value increasing from 23<sup>0</sup>C in 1960 to 26<sup>0</sup>C in 2019. The highest maximum temperature values were recorded in 2015 and 2019 when the  $T_{\max}$  value ranged between 22<sup>0</sup>C and 26<sup>0</sup>C. Lowest  $T_{\max}$  values were recorded during the 1975 and 2000, ranging between 19<sup>0</sup>C and 23<sup>0</sup>C.



### **Figure 3.9** Spatial analysis of maximum temperature

Such changes in maximum temperature are reported to result in changes in hydrological systems, significantly affecting both water availability and food security (Mohamed and Mukwada 2019), thus resulting in huge impacts on the livelihoods of communities.

The results from spatial analysis show that the change in maximum temperatures is similar across the sampled towns, with the difference of 3<sup>0</sup>C. For example, in the lower elevation zone, Marquard and Ladybrand experienced increased  $T_{\max}$  ranging between 23-26<sup>0</sup>C. Locations in the higher elevation zone, Vrede and Phuthadjithaba, experienced an increased  $T_{\max}$  of between 19 and 22<sup>0</sup>C. This implies that the sampled towns at the lower elevation experienced a hotter environment than the towns at the higher elevation. This implies that local communities in both elevation zones require more targeted adaptation measures to reduce the effects of changes in  $T_{\max}$ .

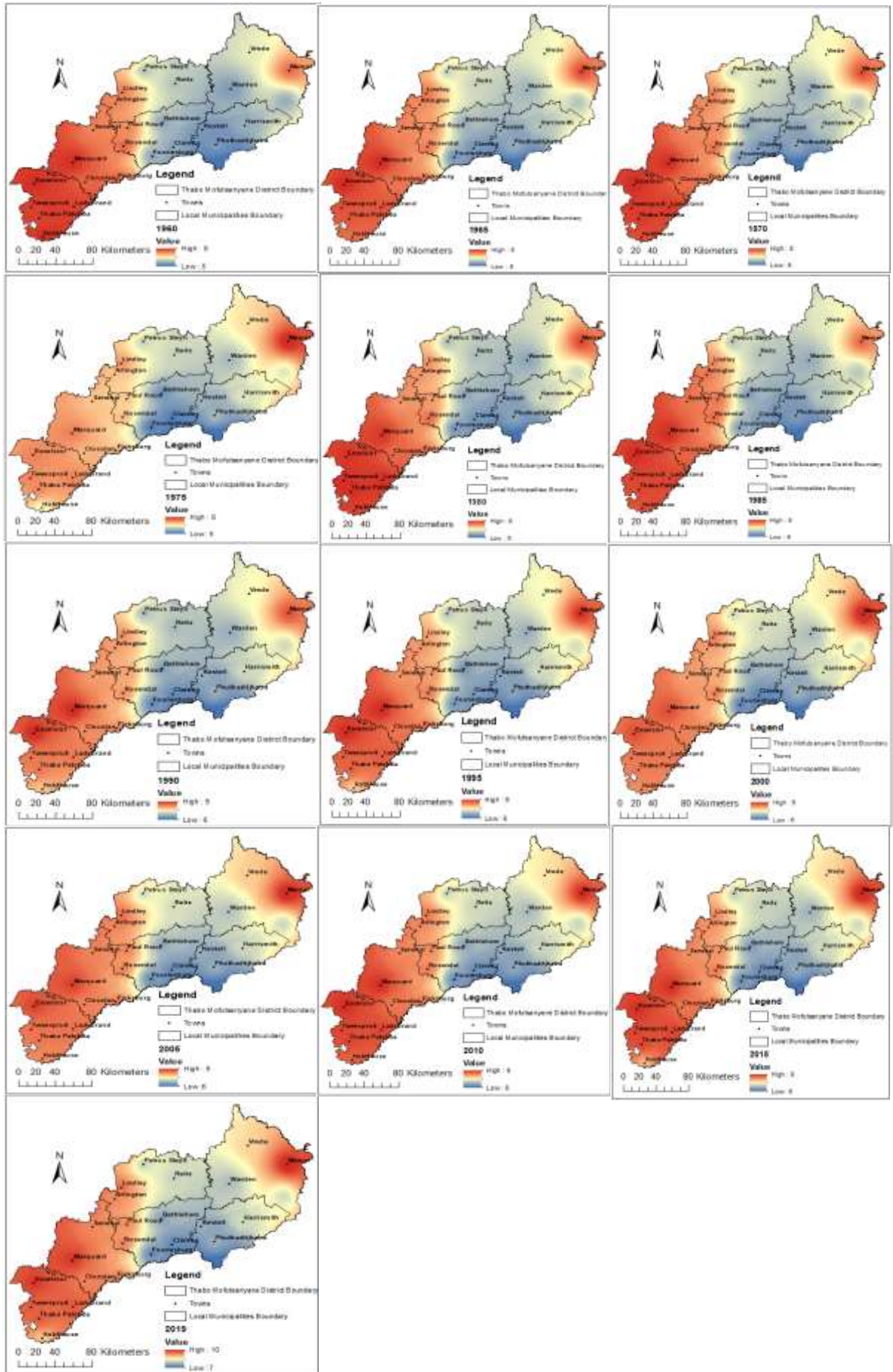
The perceptions of the respondents are in line with the observed trends. According to the perceptions reported by the respondents (Table 3.3), the respondents from Ladybrand (89.4%) and Marquard (86.4%) perceived increased summer temperatures. The same applies for the participants from Vrede (74%) and Phuthadjithaba (69%) who reported an increase in  $T_{\max}$ .

### ***Spatial analysis of minimum temperatures in the Eastern Free State Region.***

Figure 3.10 shows the spatial analysis of  $T_{\min}$  for the period 1960 to 2019. The results (Figure 3.10) indicate that the minimum temperatures in the EFSR have increased, with the average minimum temperature value increasing from 8<sup>0</sup>C in 1960 to 10<sup>0</sup>C in 2019. The highest minimum temperature values were recorded in 2019 when the  $T_{\min}$  value ranged between 7<sup>0</sup>C and 10<sup>0</sup>C. A total of four years (1960, 1965, 1975 and 1980) recorded the lowest  $T_{\min}$  values, ranging between 5<sup>0</sup>C and 8<sup>0</sup>C.

Cold winters are seen in both the high elevation zone (5-7<sup>0</sup>C) and in the lower elevated zone (8-10<sup>0</sup>C). Also, under high elevations, Vrede experiences warmer winter temperatures compared to Qwaqwa that experiences low winter temperatures. According to the survey, respondents from Marquard (71.6%), Ladybrand (63%), Vrede (56%) and Phuthadjithaba (55%) perceived a decrease in minimum temperatures. The respondents reported that the winter is becoming colder. However, some respondents from Marquard (21%), Ladybrand (30%),

Vrede (20%) and Phuthaditjhaba (17%) perceived an increase in minimum temperatures. A similar trend was also reported in Phuthaditjhaba, where the local households reported that minimum temperatures have reduced (Melore and Nel 2020). However, the respondents' perception of minimum temperature does not match with the climate records (Figures 3.7, 3.8, and 3.10).



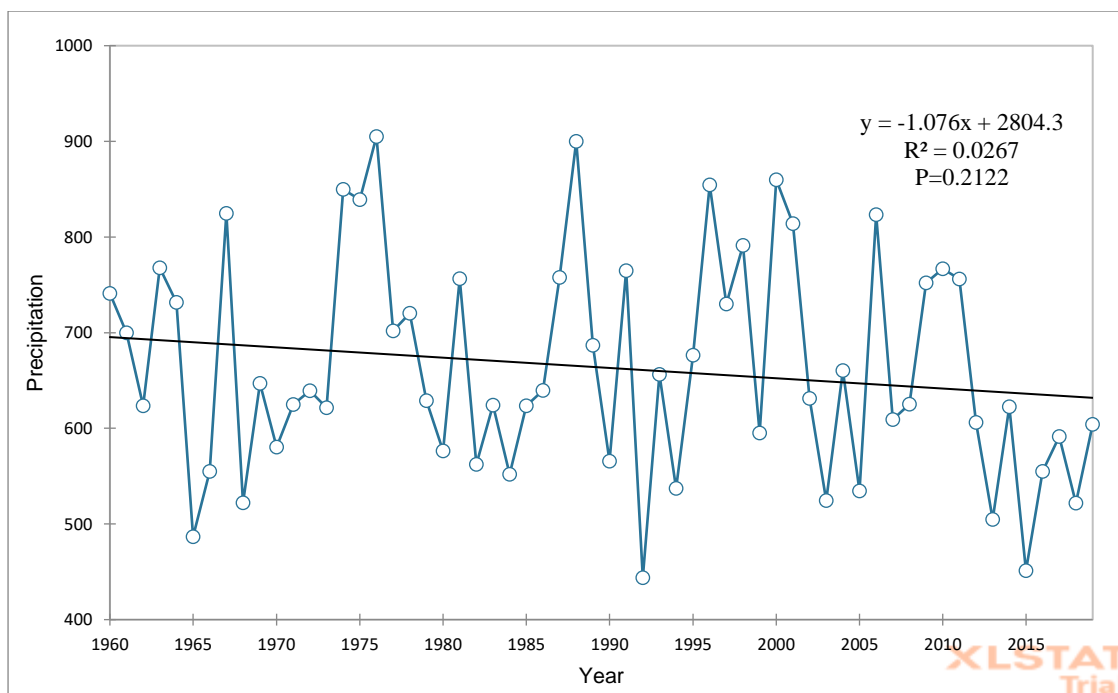
### **Figure 3.10** Spatial analysis of minimum temperature

Perceptions concerning the winter temperatures were diverse as respondents from Ladybrand (30%), Marquard (21%), Vrede (20%) and Phuthaditjhaba (17%) thought that it was increasing while Ladybrand (7%), Marquard (7.4%), Vrede (24%) and Phuthaditjhaba (27%) of them believed that there was no change. However, their opinions do not correspond to the climate records (Figure 3.7, 3.8 and 3.10). This could be because the local communities, particularly those who have stayed in the area for a lengthy period, have noticed that the winter season has become warmer. A female respondent aged above 61 years from Qwaqwa, for example, stated that, "There used to be snow on top of these mountains, but that has changed as the winter is warm and there is rarely snow." Another Qwaqwa respondent mentioned, "The winter is now warm. We used to know the winter season as overcast, but this has changed, as recently the sky has become clear during winter." The climate records showing increased winter temperatures support these household perceptions of minimum temperature.

Respondents reported that they incur high costs to provide warmth for their households during the winter, based on their perception of reduced  $T_{\min}$ . Some respondents reported increased purchases of gas and firewood to provide warmth due to lower low temperatures. According to Moeletsi et al. (2016), early frost onset and late frost cessation risks occur in the region's east and south-eastern parts. This may have contributed to local communities in high elevation zones spending more money to provide warmth than those in low elevation zones. Furthermore, some Qwaqwa respondents reported that there is no moisture on the grass due to the warming of the winter season, hence the fodder for their livestock is dry and less palatable.

#### *3.5.3 Trends of precipitation in the Eastern Free State Region*

Figure 3.11 presents the annual average precipitation for the period 1960–2019. The mean annual precipitation of the area during this period under study was 663.6 mm, with a standard deviation of 114.9 mm. The minimum rainfall recorded was 443.9 mm and the maximum recorded rainfall was 905.1 mm.



**Figure 3.11** Annual average precipitation during the period 1960–2019.

### ***Mann Kendall Test***

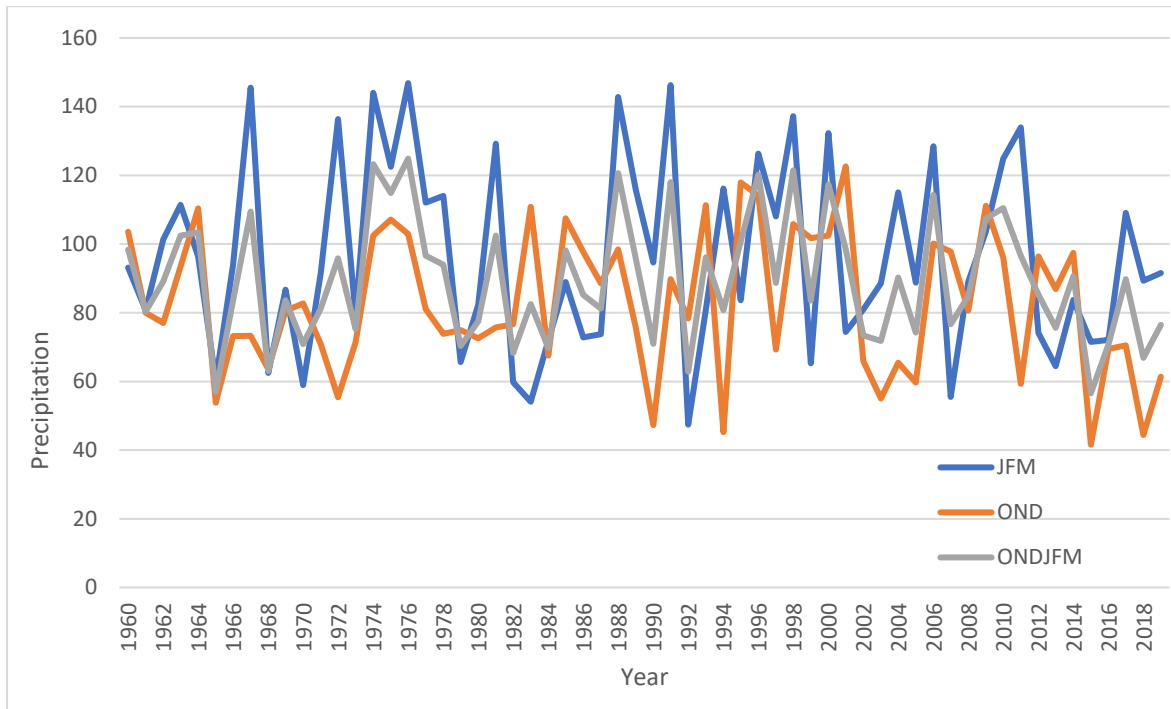
Average precipitation data series were analysed using the MK test on an annual basis. Table 3.6 results indicate the p-value is higher than the significance level (0.05), which means one rejects the alternative hypothesis ( $H_1$ ) and accepts the null hypothesis ( $H_0$ ). The results show that there has been a decrease in rainfall, but insignificant at a 5% significance level since the computed value (p-value (0.174) > 0.05). Sen’s slope of annual mean precipitation was -1.064mm/annum. A similar trend was observed in in Kongwa District and Bahi and Mpwapwa stations, Dodoma Region, Tanzania, where a non-significant decreasing trend in annual precipitation was detected (Mkonda and He, 2017; Myeya, 2021). On the contrary, the findings do not concur with the study conducted in Kilembe subcounty, Kasese District, Uganda, which indicated a statistically significant increase in annual rainfall trend (Tibara et al. 2021).

**Table 3.6** M. K test results of average annual precipitation

<b>Statistic Description</b>	<b>Temperature Data</b>
Observations	60
M.K Statistic (S)	-214.00
Kendall’s Tau	-0.121
P value (Two-tailed)	0.174

Alpha	0.05
Sen's slope	-1.064
Test interpretation	Reject $H_1$

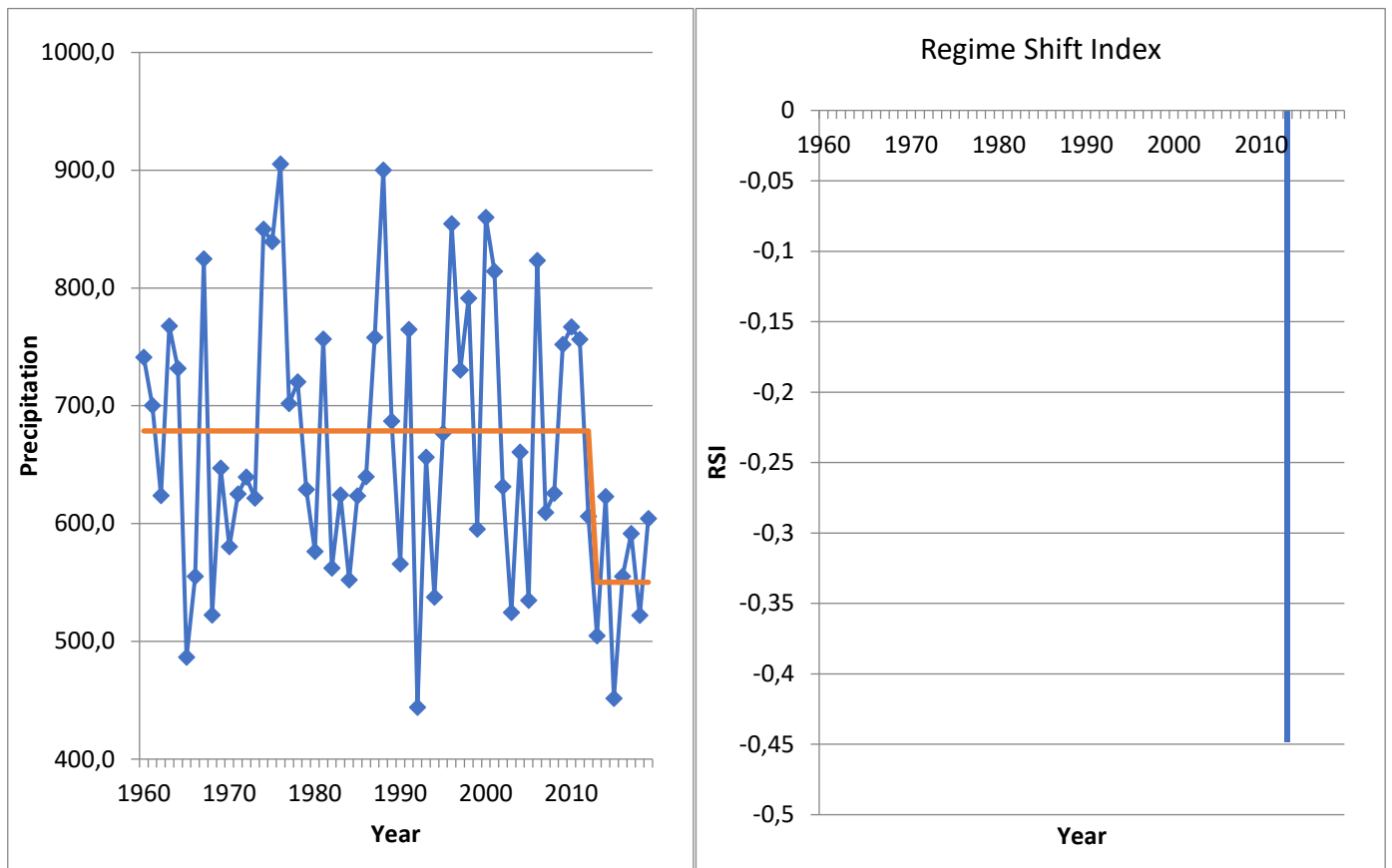
Figure 3.12 illustrates the distribution of seasonal average precipitation JFM, OND and ONDJFM over the Eastern Free State Region.



**Figure 3.12** Seasonal average precipitation for JFM, OND and ONDJFM (1960-2019)

### *Change Point Detection*

With respect to the regime shift in the mean for average precipitation shown in Figure 3.13, one shift occurred in 2013 with RSI of -0.4486. The results imply that the region has experienced reduced rainfall, hence compromising water sources for the communities and its economic activities.



**Figure 3.13** Shifts in the mean for precipitation, 1960-2019. Target  $p=0.05$ , cutoff length=10, turning point=2

#### 3.5.4. Drought Indices

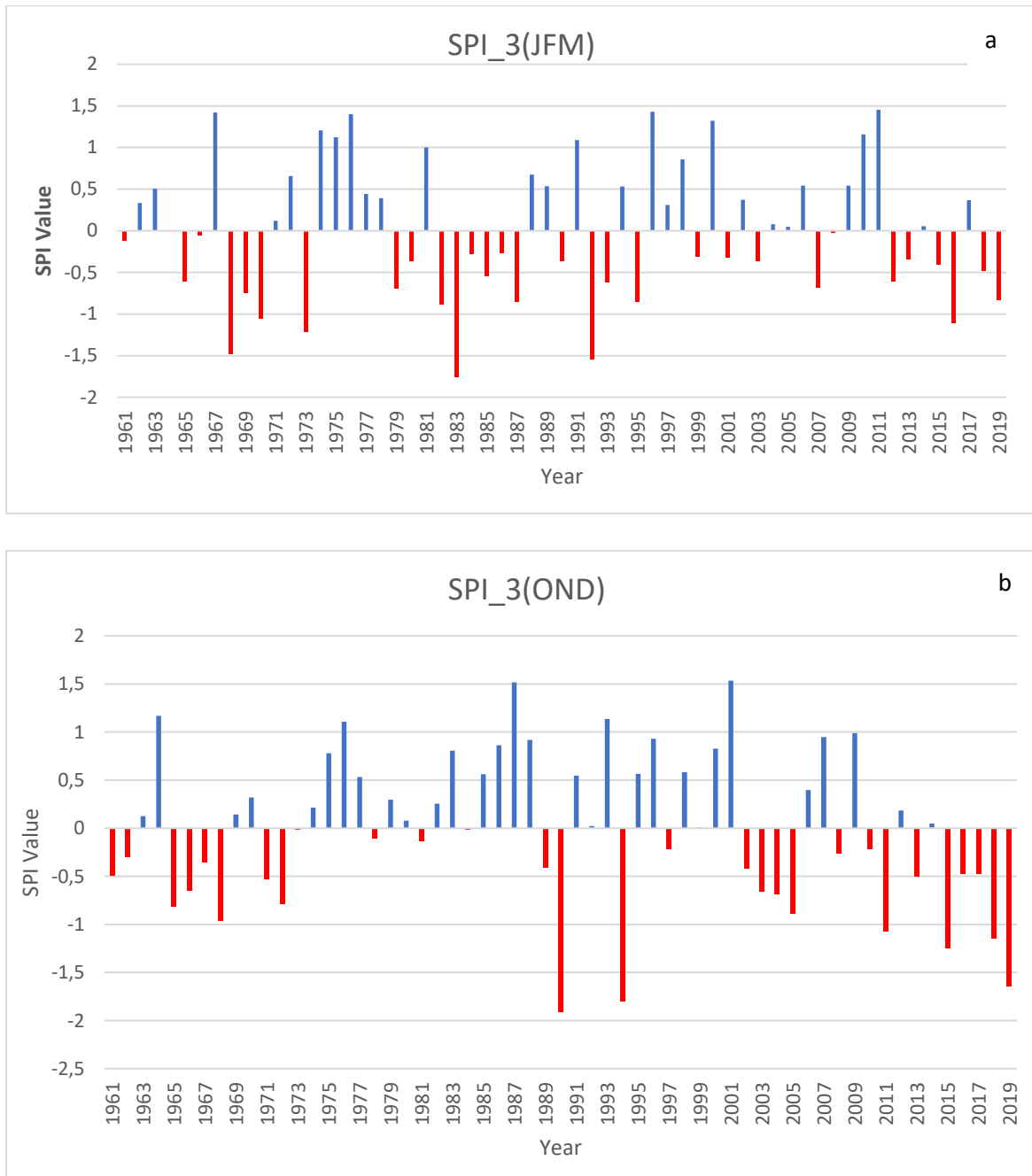
The SPI was calculated for the months of January to March (JFM), October to December (OND), and October to March (ONDJFM) season /sub-seasons for the EFSR.

#### *Drought intensity variations*

The seasonal averaged SPIs for the EFSR were plotted for the three seasons: JFM, OND, and ONDJFM for the 1961-2019 period. The findings in Figure 3.14 (a) and (b) and Figure 3.15 show the SPI fluctuations over a period of time for the entire examined seasons.

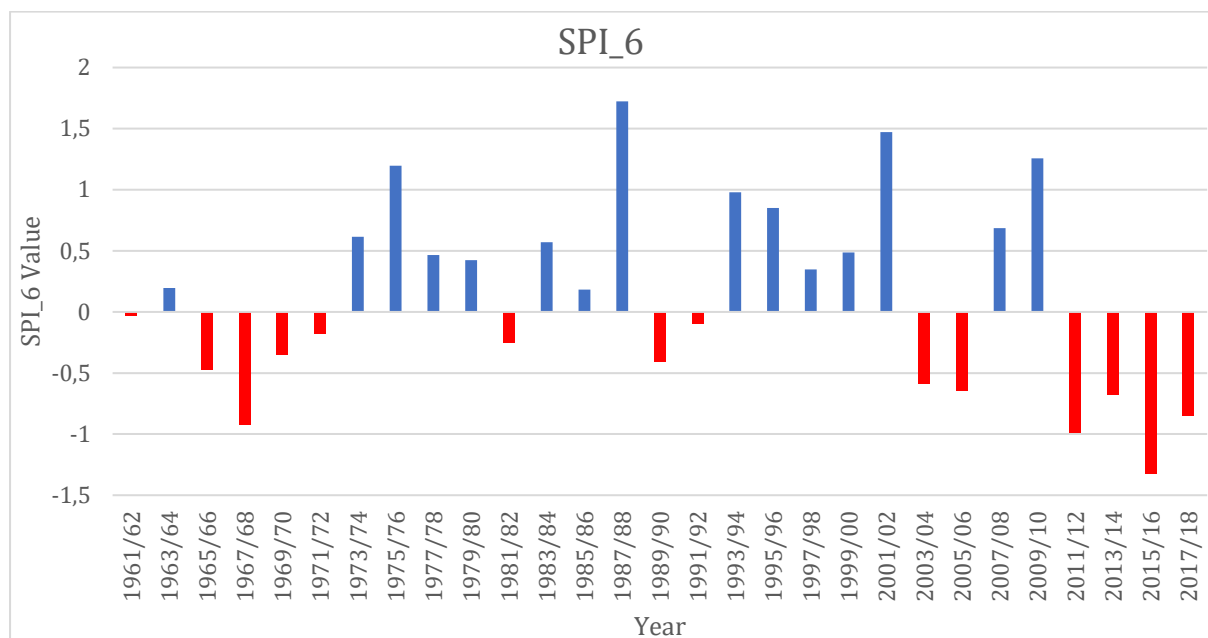
The severe droughts occurred in the years 1973 (-1.21), 1983 (-1.755), 1992 (-1.55), and 2016 (-1.10) during the JFM subseason. Intense droughts occurred in the 1990 (SPI= - 1.91) JFM subseason. The OND seasons' most intense droughts were recorded in 1994, 1990 and 2019, all with SPI < -1.645. The other three OND seasons that encountered moderate droughts were observed in 2011, 2015 and 2018. The findings highlighted by Abubakar, Newete, and Scholes (2020) indicated that the Setsoto Local Municipality, Free State, had experienced moderate-to-

extreme drought conditions with 4–6 drought event years over the 35year period. The reason for more years of drought events during OND season compared to JFM might be due to one of the observed changes in precipitation patterns that were reported by the respondents during the survey.



**Figure 3.14 a and b** SPI<sub>3</sub> (JFM and OND) and SPI<sub>6</sub> (ONDJFM) from 1961-2019

The respondents stated that the rainy season started late during the OND season and ended late during the JFM season, indicating more rain received in JFM compared to OND. Most respondents perceived drought would lead to changes in water quantity. Dramatic shifts are expected in the precipitation patterns because of incidents of consecutive dry years along with reduced rainfall and increasing temperatures. Consequently, this will intensify the hydrological cycle through increased evapotranspiration, reducing water yield from water bodies, and limiting water supply in the region. The JFM season identifies the following wet seasons with SPIs  $\geq 1.282$ : 1967, 1976, 1996, 2011 and 2000, respectively. In contrast, the severely wet years with SPIs above 1.282 were recorded during the OND season in 1987/88 and 2001/02, while moderately wet years were recorded in 1964/65, 1976/77 and 1993/94.



**Figure 3.15** SPI<sub>6</sub> (ONDJFM) from 1961-2018

The SPI<sub>6</sub> (ONDJFM) identified four seasons whose droughts were in wet seasons/years category, including 1975/76, 1987/88, 2001/02, and 2009/10, all of which were between moderately wet to extremely wet. There was severe drought (SPI  $\leq -1.282$ ) recognized by the SPI<sub>6</sub> (ONDJFM) during 2015/16 with SPI value -1.325. The slightly drought to moderate droughts were identified, including 1967/68, 2011/12 and 2017/18.

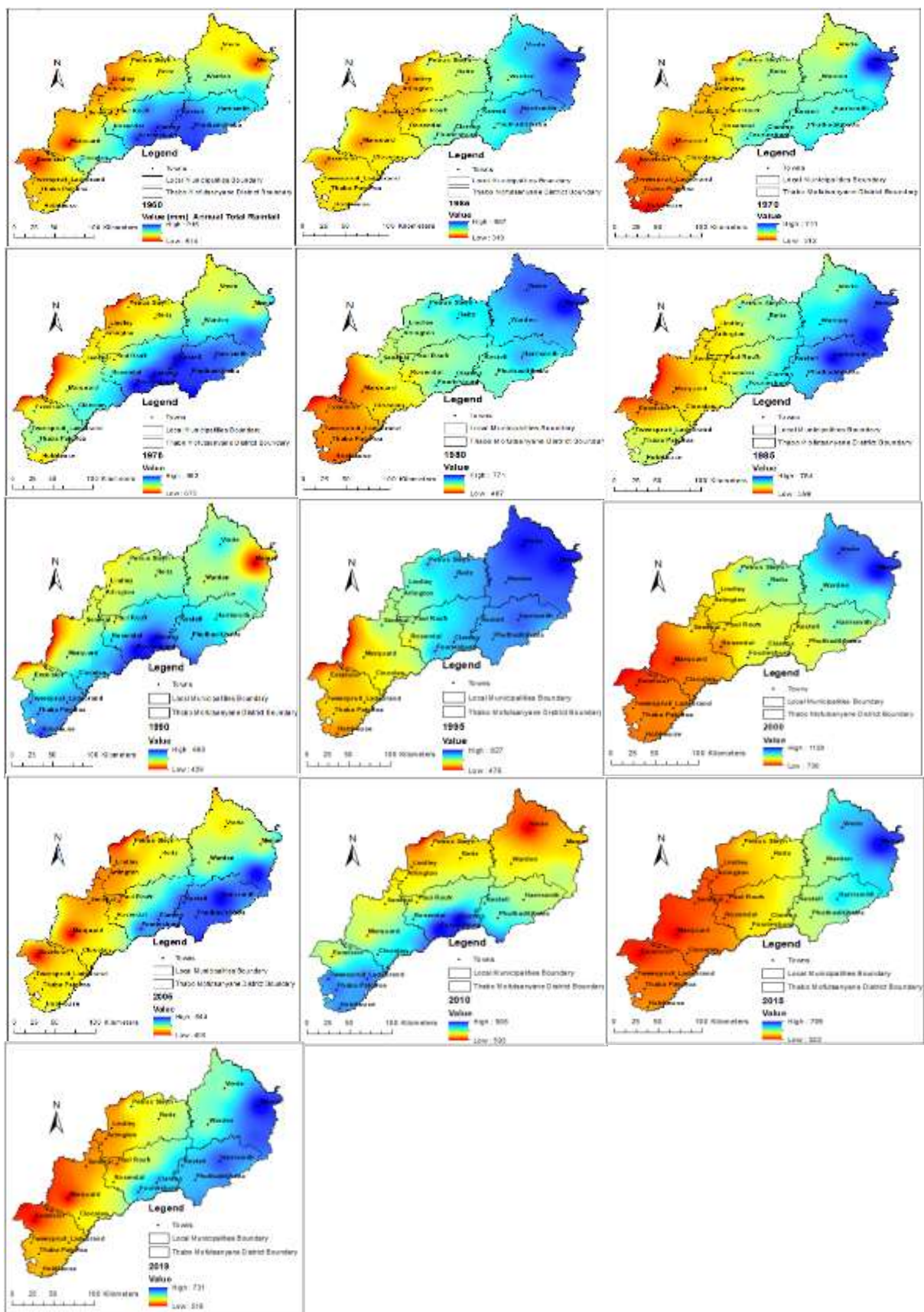
The information collected from the households revealed that they face water deficits due to drought. The results above show consecutive years of dry years from 2015-2019, indicating that the local communities have been facing droughts for some long time.

As noted above, local communities in the TMD are exposed to fluctuations in maximum and minimum temperatures and precipitation. The changes that were identified in the study's findings have consequences for both the environment and livelihoods in the region. The impact of reduced precipitation and  $T_{\min}$ , increased  $T_{\max}$  and droughts was evident in many ways. Consequently, the respondents highlighted a shift in livelihood activities. Most respondents reported that they had stopped some of the livelihood activities that were related to climate due to climate change. Indirect impacts include rising prices for industrial and agricultural supplies when water scarcity worsens, increasing the cost of products like food (Mohamed and Mukwada 2019), which may impact the livelihoods of communities in the area.

### *3.5.5 Spatial analysis of total annual precipitation in the Eastern Free State Region*

Figure 3.16 presents the temporal and spatial analysis of annual precipitation from 1960–2019. The results (Figure 3.16) show that the average total precipitation values differ markedly across the region. The highest annual precipitation value was recorded in 2000, when the value ranged between 738 mm and 1120 mm. The lowest annual average precipitation value was recorded in 1965, when the value ranged between 319 mm and 687 mm. A significant drop in annual precipitation was experienced in 2000 when the highest precipitation values ranged between 738 mm and 1120 mm and in 2005 when they ranged from 408 mm to 644 mm. High rainfall is more prominent in the south or eastern part of this region, especially in the high elevation zone (Phuthadjithaba and Vrede). However, under the high elevation zone, the spatial analysis shows that Phuthadjithaba receives more years of high rainfall than Vrede. Also, the years of high rainfall varied between the two towns. However, while the spatial analysis may show that Qwaqwa receives more rainfall, respondents' perceptions suggest otherwise.

Among the sampled households in Phuthaditjhaba and Vrede 51% and 50% respectively perceived reduced rainfall over the past years. The respondents from Qwaqwa village said they had experienced low rainfall and erratic rains that have resulted in the drying out of water bodies, leading to reduced water availability for the local communities. From Vrede, one of the respondents, reported that the Emanzini Dam dried up due to the drought and low rainfall, leading to the local communities facing water shortages. However, some respondents in this high elevation zone reported that the rain has increased, 32% in Vrede and 41% in Phuthaditjhaba.



**Figure 3.16** Temporary and Spatial distribution of annual total precipitation

The spatial analysis showed that the sampled towns in the low elevation zone experienced low rainfall compared to the high elevation zone. According to the analysis, the sampled towns at low elevation (Ladybrand and Marquard) had the lowest rainfall in 1965 (319 mm) and 2015 (322 mm). This is consistent with the perceptions held by the respondents from Ladybrand (68 %) and Marquard (38%), who reported a decrease in rainfall, respectively.

The respondents from this part of the region also reported incidents of water shortages, affecting both agriculture-based and socio-economic activities since 2015. The water crisis is a serious issue reported in the selected towns, and the local communities are facing issues in accessing safe and ample amounts of water to drink and household consumption. On the contrary, under the low elevation zone, in Marquard more respondents (53%) reported that the rain had increased compared to opposite opinion of reduced rainfall. Ladybrand, however, more surveyed households reported reduction in rainfall, which confirms the trend analysis.

However, most of the respondents who perceived a rise in the amount of rainfall received were referencing the recent increase in rainfall during the JFM season. Figure 3.11 indicates that though there was a sharp drop in precipitation from 2015–2018, the analysis shows an increase in seasonal precipitation from 2018–2019. This might indicate that since 2019 up to the time the survey was done (2021 July), the local communities have been experiencing higher rainfall during the JFM/OND season compared to the previous years. For example, some respondents from Ladybrand and Marquard said the following: "We had too much rain this year (2021)." "We had too much rain last year," he said. "Past years there was no water, but last year and this year we had more rain." We had early rain this year and last year we had more rain than usual. Other respondents from Phuthadjithaba and Vrede also noted similar reports concerning receiving more rain in recent years, saying, "In the last 5 years the rain has been less, but we received good rain last year." This might indicate that it is easier for some local communities to perceive recent changes in climate or extreme events related to climate variability than the events that occurred some years before.

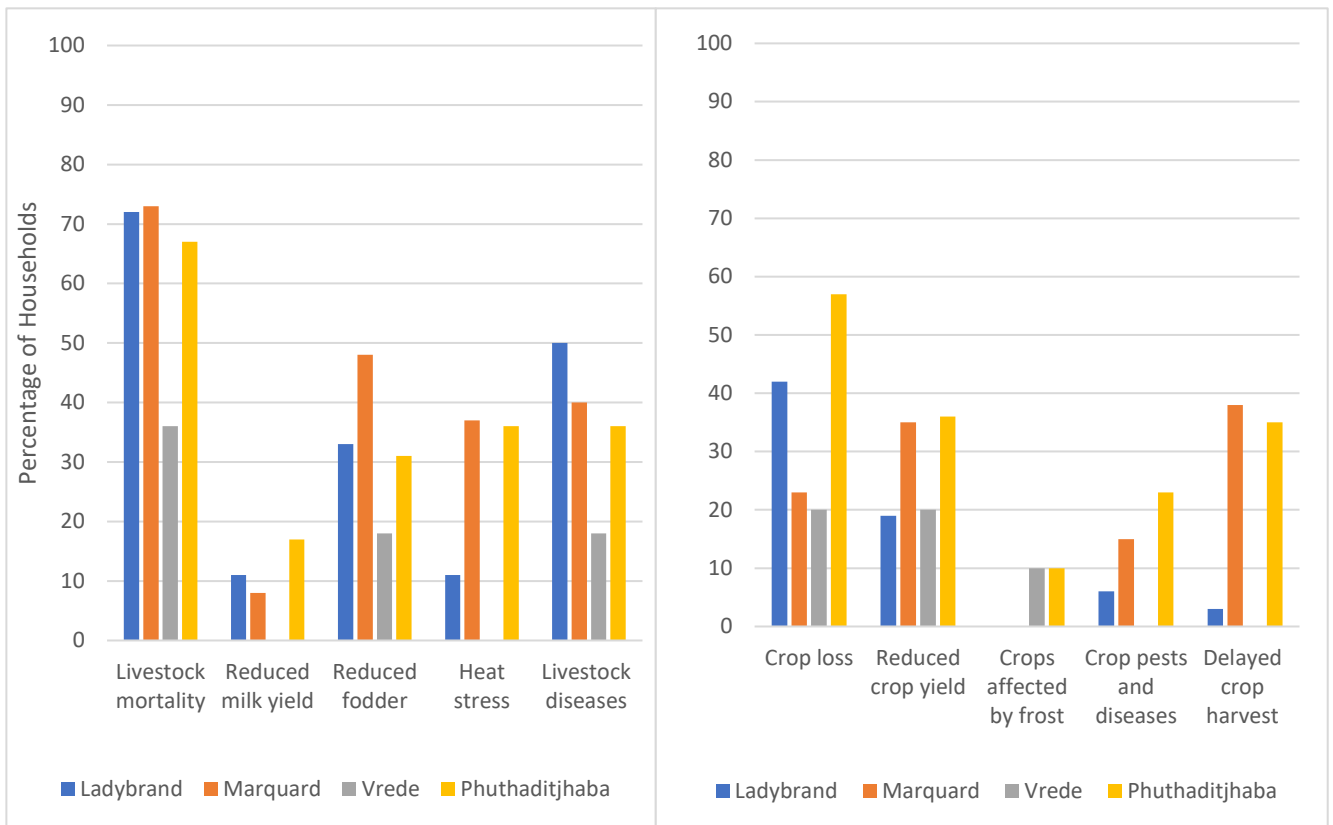
Among the household members interviewed in the EFSR as a whole, agriculture-based livelihoods have reported the implications of fluctuations in rainfall as reduced crop yields, as well as reduced quality of pastures, and lower winter fodder production. Late onset of rainfall and late cessation of frost might also contribute to alteration of crop calendar, delayed harvest

and reduced crop yields and livestock fodder for the local communities. Moeletsi and Tongwane (2017) assert that medium-late season maize varieties planted in November in most of the south-eastern and eastern parts of this region face high crop failure risks because of frost incidences during the months of April and May.

### **3.6 Perceived impacts of climate change and variability**

The impacts of climate change and variability were recognized by the respondents in the region (Figure 3.17). The respondents (90.5%) from the sampled towns indicated that climate variability and change impact their livestock and crop-based livelihoods, reduce water availability for crops, livestock, and domestic purposes, thus affecting their socio-economic systems. This shows that the households in the EFSR are vulnerable to the effects of climate change that directly and indirectly affect their livelihoods. Only thirty-eight (9.5%) of the respondents reported no impacts of climate change and natural disasters on their livelihoods.

Slightly more than fifty percent of the respondents expressed concern about reduced availability of water as a result of low precipitation, increased summer temperatures and drought incidents. The respondents reported that water shortages have resulted in increased labour, as many household members travel long distances to fetch water for household purposes, as well as for their livestock, and for backyard gardening. Due to water scarcity, households that depend on on-farm activities, experience low crop yields and shortages of water for domestic purposes and livestock, leading to low on-farm income and increased food prices. Figure 3.17 shows the impacts of climate change on crop-based and livestock-based livelihoods in the region.



**Figure 3.17** Perceived Climate change impacts and (a) Livestock farming and (b) Crop farming in the EFSR.

Livestock dependent households mentioned climate-induced impacts on livestock farming, namely, livestock diseases, reduced milk yield, reduced fodder, heat stress and livestock death. In the lower elevation zone, in Marquard in particular, most respondents reported incidents of reduced livestock fodder, heat stress, while in Ladybrand, most respondents reported livestock diseases and reduced milk yield. In the higher elevation zone, most respondents from Phuthaditjhaba reported increased livestock diseases, reduced milk yield, reduced fodder, heat stress, and livestock deaths compared to Vrede.

The results (Figure 3.17) revealed that households that depend on backyard gardening as their main source of subsistence faced problems such as crop loss, reduced crop yield, crop pests and diseases, delayed crop harvest and crops affected by frost due to reduced rainfall, erratic rainfall, delayed onset of rainfall, and climate hazards. Some respondents reported that they had reduced the number of crops they grow or abandoned crop farming altogether. The significant difference between the two elevation zones was that none of the respondents in the lower elevation zones reported crop damage due to frost. In comparison to the other towns, most respondents in Phuthaditjhaba reported incidences of crop diseases and pests, and crop

loss due to frost. As a result, households in the higher elevation zone should prioritize the implementation of adaptation techniques that protect crops against frost, pests, and diseases, such as the planting of frost-resistant crops and application of pesticides. The findings underline the importance of local contexts and demonstrate the need to avoid making broad generalizations about climate change implications, particularly in mountainous places (Spies 2020).

The respondents perceived the main socio-economic implications of climate change to be loss of income, health problems, labour, loss of employment, and additional costs. The respondents reported additional costs related to climate change, including buying more supplementary feed to cover for delayed regeneration of pastures due to delayed or low rainfall, buying water for drinking because of low water shortages, and buying more firewood or gas to provide warmth during cold weather. Only 20 respondents stated that reduced crop yields, and loss of on-farm employment had accelerated the loss of on-farm income. Only 26 respondents stated that they faced climate-related health problems.

### **3.7 Climate change adaptation strategies adopted by households**

The adaptation measures adopted by the households include water and soil management strategies, crop and livestock management strategies, and socio-economic strategies. The respondents (60 %) responded to water shortages by seeking alternative water management strategies such as harvesting rainwater, buying water, and storing water in containers. Purchasing of supplementary feeds (46 %), and the introduction of drought resistant livestock species (34 %) were some of the responses adopted by households to climate change. The respondents reported that they used different adaptation strategies to improve crop production, through use of different seed varieties that are drought or frost resistant (33 %), and soil management strategies (45 %) such as mulching, and application of organic and inorganic fertilizers. Households used different organic fertilizers such as livestock manure, vegetable leaves, maize stalks, grass, and tree leaves to improve soil fertility. Limited adoption of measures such as growing frost resistant crops and soil management strategies may be due to lack of knowledge or resources to implement advanced measures at a household level. The findings are supported by (Abid et al. 2019), who reported that a lack of information and resources are constraints to the implementation of climate change adaptation methods.

Income diversification was one of the primary activities that the respondents were engaged in to pursue additional income sources. Some respondents mentioned self-employed activities related to construction, trading, shop ownership, land leasing, and moneylending, as their main

adaptation strategies. The households diversified their on-farm revenue by selling livestock, livestock and crop products, fodder, forest resources, and leasing out portions of farmland. Remittances (18 %), government wages (49 %), pensions (26 %), and grants (24 %) were among the other sources of income mentioned by the respondents. This indicates that the households in the EFSR were engaged in more than one source of income in order to adapt to climate change. Engaging in different livelihood strategies buffers households from the uncertainties of climatic risks. According to Brown et al. (2019), rural households with a greater diversity of assets and livelihood options are likely to be more resilient because of a higher capability to substitute alternative livelihood strategies in periods of climatic stress, especially when alternative livelihood options differ in exposure to external pressures. Several studies have been reported regarding local households who took loans, pursued additional income sources (sold labour, revenue from the small shop), and sold livestock to repair damaged houses and recover from agricultural losses (Qaisrani et al. 2018; Brown et al. 2019).

Some respondents reported that they receive help from neighbours and/or relatives within the same or outside town to cope with climate change impacts. Fifty-four percent of the respondents reported that they received help from relatives, friends, and neighbours. Provision of temporary jobs, assistance in partaking cultural activities, sharing of income and labour amongst households, lending money from family members or neighbours, receiving food, water, livestock feeds, livestock manure, and rendering labour to affected families are some of the social relation activities listed by the respondents as climate change adaptation strategies. The respondents acknowledged that having access to social relationships through families and communities improved access to resources and lessened the impact of climate change and harsh climate events.

### **3.8 Conclusion**

The variability and trends in the EFSR's annual average minimum-maximum temperatures, precipitation, and SPI 3 (JFM and OND) and SPI 6 were studied over a 59-year period. The M.K tests show annual minimum temperature and minimum temperature in dry seasons are increasing respectively. The data indicate a statistically significant trend with  $p < 0.05$  for minimum-maximum temperatures. The (SRSD) method (change point detection method) results showed an abrupt shift in maximum and minimum temperatures, and precipitation. Such trends in temperature and precipitation have implications for agricultural activities as the region's agricultural potential is primarily rain-fed and subsistence in practice, which further worsens the socio-economic conditions of the local households. SPI data show that severe

droughts occurred during the JFM subseason in 1973 (-1.21), 1983 (-1.755), 1992 (-1.55), and 2016 (-1.10). Droughts were severe in 1990 (SPI= -1.91) during the subseason (JFM). The most severe drought events in the OND seasons were recorded in 1994, 1990, and 2019, all with SPI -1.645. The recurrence of negative SPI values in the time series might signify increasing aridity in the region. The findings indicate that the OND season experiences more years of drought than the JFM sub-seasons, which can be disastrous when they occur during the growth season. Most respondents cited an increase in summer temperatures, a decrease in winter temperatures, changes in precipitation patterns, a decrease in precipitation during the OND and JFM seasons and increasing drought episodes. The respondents' views of changes in maximum temperature, precipitation, and droughts are consistent with climatic data. All in all, the local communities in Thabo Mofutsanyane District are vulnerable to variations in temperature and precipitation, and drought conditions. Having a better understanding of how climate risk is changing enables households to make particular adjustments to their livelihood patterns. The respondents reported that their lives and livelihoods had also shifted due to changes in climate, leading to implications for the agricultural and socio-economic systems. Water and soil management strategies, crop and livestock management strategies, and socio-economic strategies are among the adaptation strategies used by the households. Therefore, it may be concluded that combining local knowledge and knowledge on community's perceptions of climate change with readily available scientific information could increase the capacity for climate change adaptation.

### **Author Declarations**

### **Competing interests**

The authors have no relevant financial/ non-financial interests to disclose.

### **Funding**

This research was supported financially by the National Research Foundation (NRF).

### **Disclosure statement**

The authors report there are no competing interests to declare.

### **Ethics approval**

Prior to the start of the study, ethical approval was attained from the University of the Free State's General/Human Research Ethics Committee (GHREC) (Ethical Clearance number: UFS-HSD2020/1277/0709).

**Consent to participate**

An informed written consent to participate in the research was obtained from each participant.

**Data availability:** The datasets created and examined during the present study are presented in the main manuscript.

## CHAPTER 4: AN ASSESSMENT OF THE PERCEPTIONS OF LOCAL COMMUNITIES IN THE EASTERN FREE STATE REGION OF SOUTH AFRICA REGARDING THE IMPACTS OF CLIMATE CHANGE ON LIVELIHOODS

### 4.1 Brief chapter synopsis

This chapter centres on the article which has been submitted to a journal for publication as

Msimanga, L.\*, & Mukwada, G. (2022). An Assessment of the perceptions of local communities in the Eastern Free State Region of South Africa regarding the impacts of climate change on livelihoods. *Transactions of the Royal Society of South Africa*

### 4.2 Abstract:

Mountain communities are adversely affected by climate change and variability causing significant challenges to their livelihood strategies. The objective of this article is to examine the perceptions of local households in the Eastern Free State Region, South Africa about climate change impacts on their livelihoods. A multistage sampling process was employed to select 400 participants. A semi-structured household questionnaire survey was utilized to gather information about the impacts of climate change on livelihoods. The most significant climate change impact was reported as declining water quality and quantity (67 %), which has resulted in significant changes in local communities' livelihood activities. Crop loss (48 %), reduced crop yields (33 %), animal diseases (38 %), and livestock mortality (68 %) were all reported by agriculture-based households. Households also cited climate-related socio-economic impacts- higher prices, farm and non-farm income loss, and increased labour. The findings reveal that climate change effects on on-farm and off-farm activities reported by households were contextualized according to households' primary livelihood activities. In conclusion, understanding the local communities' perceptions about the effects of climate change on their livelihoods could be useful for identifying context-specific adaptation strategies.

**Keywords:** Climate change; Households; Off-farm livelihoods; On-farm Livelihoods; variability.

### 4.3 Introduction

Rural livelihood studies have become a central part of development initiatives and the role of climate change on these livelihoods has become an important discourse. Since Chambers and Conway raised the issue of sustainable rural livelihoods in the early 1990s, livelihood scenarios

have become a focal point in development discussions (Pauli et al. 2016). Rural livelihood strategies are heavily reliant on activities such as farming, livestock herding, and the use of natural resources through hunting, fishing, and gathering, while other strategies rely on rural labour markets, migrant labour, and self-employment in the non-farm economy (Piya, Joshi, and Maharjan 2016). However, there, has been a constant shift in the livelihoods of rural populations due to climate change such as changes in nature of economy from traditional agricultural activities to tourism based activities, and food insecurity and crop loss (Chersich and Wright 2019; Yiridomoh, Sullo, and Bonye 2021; Chhetri et al. 2020; Saalu, Oriaso, and Gyampoh 2020; Nsubuga et al. 2021). According to a recent study by Mechler et al. (2020), climate change has long-term and direct impacts for vulnerable people and countries. Consequently, such impacts need to be examined in detail as they are critical in the development of these communities and countries. Rural livelihoods are impacted by climate change and without appropriate adaptation strategies, development strategies are rendered ineffective.

In many societies, decisions about how to make a living are made at the household level (Nsubuga et al. 2021), hence how a household perceives climate variability and change, and how these climatic conditions affect them is important. Climate change and variability have consequences for the livelihoods of vulnerable people who rely on natural ecosystems for survival. Several studies have established that households that depend on natural resource-based livelihoods are far more susceptible to the effects of climate change and variability and natural disasters (Ghosh and Ghosal 2020; Nsubuga et al. 2021). Research on household level socioeconomic implications of climate change has largely gone unnoticed, particularly in mountainous regions.

Livelihood is a complex system with environmental, economic, social, and institutional components that drive the evolution of individuals' interactions with their geographical surroundings (Lan et al. 2021). Various conceptual frameworks have been developed to explore the vulnerability and sustainability of livelihoods in cases of climatic change and natural hazards. For example, Utete et al. (2019) used the Livelihood Indicator Approach (LIA) to assess how different livelihood strategies adopted by semi-urban fishing populations were affected by climate stressors on the around Lakes Manyame and Chivero in Zimbabwe. Another study applied the Livelihood Vulnerability Index (LVI) to analyse the current understanding of climate change impacts on the livelihoods of two major cocoa farming districts in Ghana based on chosen indicators (Amoatey and Sulaiman 2020). The weakness of

the indicator approach is that there is some subjectivity in choosing indicators (Etwire, Al-Hassan, and Kuwornu 2013), and the local environment plays a significant part in designing and framing the indicators. A study by Rehman and Azhoni 2022 elaborated on the perceptions of households concerning climate change and the effects of climate change on livelihoods in Arunachal Pradesh, India, using Livelihood Vulnerability Index (LVI-IPCC). A critical question that has not been addressed in the LVI-IPCC literature to date is how to select a unit of aggregation that captures diversity across a climatically varied area while also being generalizable enough to inform adaptation strategies beyond the specific communities surveyed (Simane, Zaitchik, and Foltz 2016).

The Sustainable Livelihood Framework (SLF) has been extensively used to evaluate livelihood sustainability (Donohue and Biggs 2015; Pandey et al. 2017; Ming et al. 2019; Islam, Islam, and Habib 2020). Compared to the other mentioned frameworks, the SLF allows for people-centred developments by allowing contextualised insights about climate change implications on livelihood to develop the bottom-up measures of livelihood resilience. In this regard, this study adopted the SLF proposed by the Department of International Development (DfID) to provide a detailed assessment of the perceptions held by the households regarding the impacts of changes in precipitation, temperature, and extreme events on their livelihood activities. Unlike previous studies that limited their scope to the traditional five categories of livelihood assets (physical assets, natural assets, financial assets, human resource assets, and social assets), this study includes geographical advantage and settlement types, which may influence how the households perceive environmental changes and their impacts based on altitude and settlement type.

The EFSR of South Africa is among the most productive mountainous agricultural regions in the country (Dube et al. 2019). The natural- resource based systems that local people depend on for livelihood include commercial farming, small-scale farming, subsistence agriculture, pastoralism, and trade in medicinal herbs (Tongwane et al. 2017; Myeni et al. 2019). Although agriculture is the principal occupation in this region, off-farm income has become the primary income source for most households. The occurrence of climate-related disasters in this region has been documented by several authors (Moeletsi, Tongwane, and Tsubo 2016; Mohamed and Mukwada 2019; Melore and Nel 2020). Nonetheless, there is limited evidence on how climate change affects both the on-farm and off-farm mountain livelihoods of local communities in the region. Using empirical data, this study investigates perceptions of households on climate change and its implications for the on-farm and non-farm livelihood

activities, and socio-economic systems. The findings of the study would help in closing the knowledge gap regarding climate variability and change impacts on local communities in this region. According to Talanow et al. (2020), understanding how local communities perceive and respond to climate change is fundamental for developing sustainable climate adaptation strategies. As a result, it is critical to understand the perceptions and views of local communities regarding the impact of climate change in both biological and socio-economic systems, to develop effective adaptation techniques that are tailored to the local context. Therefore, the objective of the article is to investigate the perceptions of local households in the EFSR of South Africa about the impacts of climate change on their livelihoods.

#### 4.4 Materials and Methods

##### 4.4.1 Study Area

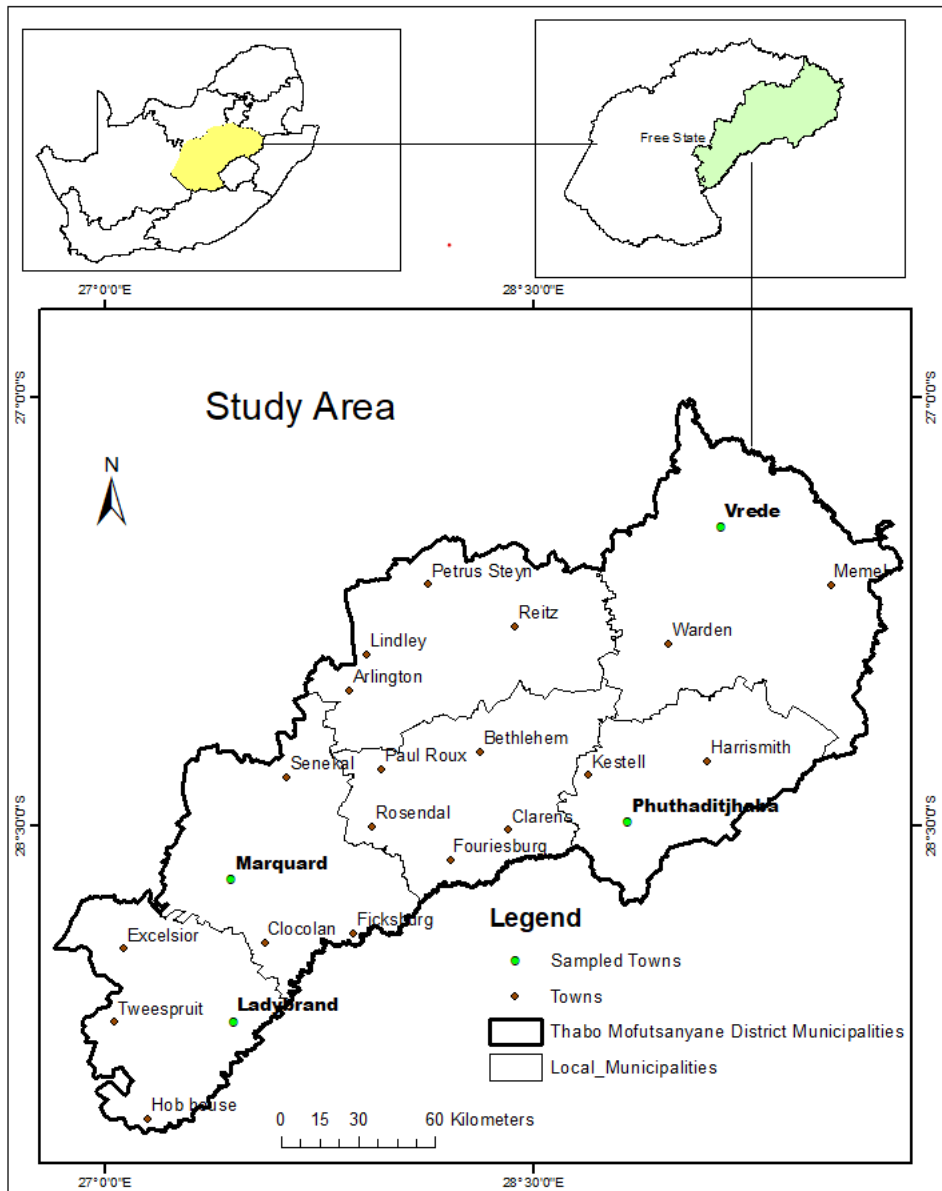
The research study was carried out in TMD, which is in the EFSR of South Africa (Figure 4.1). The EFSR mainly comprises the TMD, bounded by the Drakensberg and Maluti Mountains, Lesotho, KwaZulu Natal and Eastern Cape provinces. The district comprises six local municipalities: Setsoto, Dihlabeng, Nketoana, Maluti-a-Phofung, Phumelela and Mantsopa. Four local municipalities, namely Maluti-a-Phofung and Setsoto, were selected for the study. The selection was based on altitude and population size. These municipalities were the Maluti-a-Phofung, Phumelela, Sesotho and Mantsopa local municipalities. Their locations and population sizes are noted in Table 4.1.

**Table 4.1** Location and population sizes of the local municipalities.

Elevation Zone	Local Municipalities	Population size	Number of Households
High Elevation	Phumelela	50 054	14 586
	Dihlabeng	140 044	46 857
	Maluti-a-Phofung	353 453	110 725
Low Elevation	Setsoto	117 361	37 246
	Mantsopa	53 525	16 951
	Nketoana	64 894	19664

In TMD, rural settlements are mostly found at the periphery of the small towns. Also, these small towns are linked with surrounding small-scale/subsistence/commercial agricultural areas, as well as villages. Melore and Nel (2020) state that the smaller towns and villages are

vulnerable to political, economic, and social risks exacerbated by climate change. Thabo Mofutsanyane has the highest non-urban population (59.8%) in the Free State Province as a whole, which is one of the reasons why it was selected for this study.



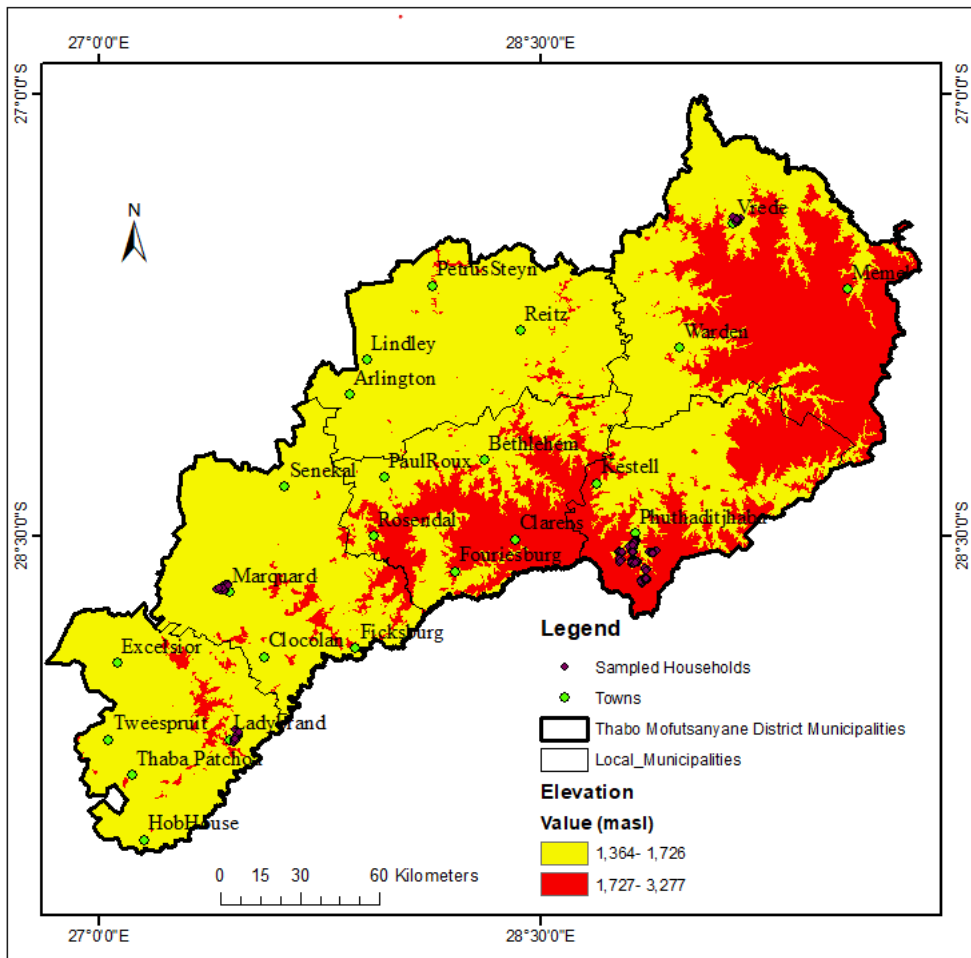
**Figure 4.1** Location of study area. Source: Authors

### *The Environmental conditions in the Eastern Free State Region*

#### *Elevation*

Rugged landscape is a defining feature of the EFSR. According to Moeletsi and Walker (2012), its topography is mountainous, with altitudes ranging approximately between 1500 and 3000 metres above sea level (masl) at the peak of Maluti-Drakensburg Mountain. Based on Figure

4.2 below, the elevation of the local study municipalities varies from 1364-1726 masl (lowest elevation) to the highest elevation (1727-3277 masl).



**Figure 4.2** Relief of the EFSR, and Sampled Towns showing the Sampled households.  
Source: Authors

*Climatic Conditions*

The Free State Province is mostly semi-arid except for the eastern and north-eastern parts, where humid subtropical climate conditions are experienced (Moeletsi, Walker, and Adolf 2011). Moeletsi and Walker (2013) state that the southern and western parts of the Free State Province receive less than 400 mm rainfall while the eastern part receives precipitation that ranges between 500-600 mm. The eastern part of the region receives higher rainfall than other areas of the province (Mbiriri, Mukwada, and Manatsa 2018), making it more suitable for rainfed crop production compared to the rest of the province (Moeletsi and Walker 2013). In the EFSR, the mean maximum temperatures range between 20<sup>0</sup>C and 22<sup>0</sup>C, while minimum temperatures range between 5<sup>0</sup>C and -1<sup>0</sup>C (Dube et al. 2019). The risk of **frost attack** varies significantly in the study area due to the contrasting topography and geographical aspect, with

the early onset of frost and late cessation of frost risk occurring over the south-eastern and east parts of the region (Moeletsi, Tongwane, and Tsubo 2016).

#### *4.4.2 Research design*

The study used a combined qualitative and quantitative research methods. The SLF proposed by the (DfID, 2001) was used to frame the research study. Aazami and Shanazi (2020) state that the SLF is best applied when working with qualitative and quantitative methods. The mixed method facilitated data triangulation and provided a variety of sources of information to create a detailed interaction between rural livelihoods and changes in environmental, socioeconomic, development, and policy over time.

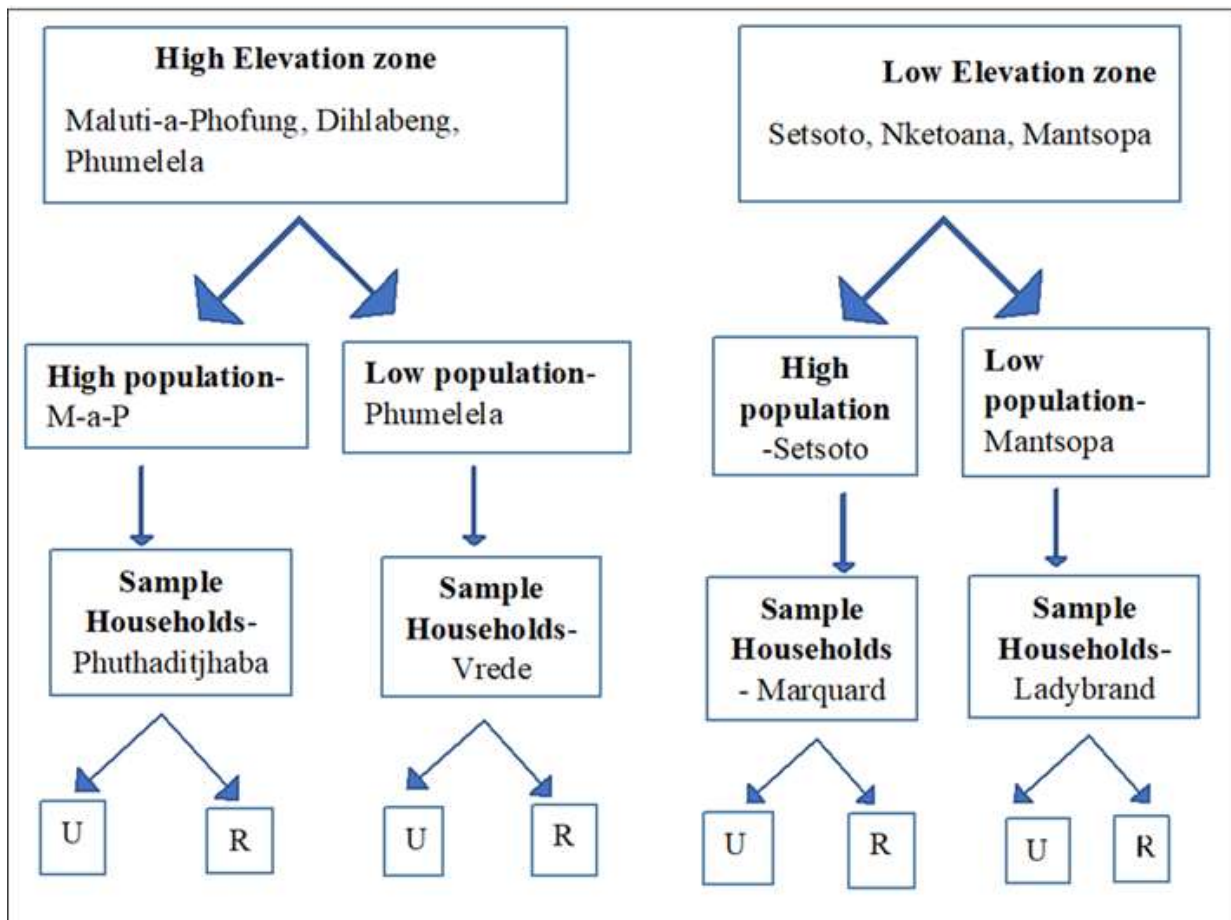
As part of the quantitative study design, a structured questionnaire was used. Part of the questionnaire that was used had open-ended questions to allow the participants to elaborate on their responses. The design of the questionnaire was guided by the purpose of the study, which is to investigate the effects of climate change and variability on the livelihoods of mountain communities in the EFSR. The design of the questionnaire was largely guided by the (DfID 2001) SLF. Another source of data were the formal interviews that were held with two veterinary officers, one from Qwaqwa and another from Ladybrand and Marquard. The veterinary officers provided data on the impact of climate change on livestock farming. The officials were chosen for their expertise on climate-related impacts on livestock, climate-related adaptation techniques for livestock farming, and characteristics that may affect the adoption of climate change adaptation measures among livestock-based households.

#### ***Sampling design***

The study used multi-stage sampling. The first stage involved stratified sampling, whereby six local municipalities were divided into two altitudinal zones based on elevation- high elevation (Maluti-a-Phofung, Phumelela and Dihlabeng) and low elevation (Setsoto, Mantsopa and Nketoana) (Figure 4.2). Thus, the local municipalities were classified according to elevation based on the natural breaks classification method using ArcMap 10.7. In the study area, the highest elevation is 3277m asl, and the lowest is 1364m. High elevation was referred to as an elevation between 1669-3277 masl, and low elevation was defined as less than 1364-1668 m asl. The second stage involved selecting the study sites according to population size.

The six local municipalities were ranked according to population size, and in each altitudinal zone, the local municipalities that had the largest population and smallest populations were selected for inclusion in the study. In order to gather a representative sample of the actual

situation on the ground, the selection was based on population size. Thus, a total of four municipalities were included in the study sample. The selected municipalities under high elevation include Maluti-a-Phofung with the higher population and Phumelela with the lower population. Within the low elevation, Setsoto and Mantsopa were selected to represent high and low population municipalities, respectively. Thus, stratified sampling was undertaken in each selected settlement to include both its urban and surrounding rural environments. In each sampled settlement, households were randomly selected. Only the households in which household heads were present during the survey were included in the study.



**Figure 4.3** Criteria for selecting sample households (U- Urban areas, R- Rural areas). High elevation zone (1727-3277masl), Low elevation zone (1364-1726masl).

### ***Study population***

To get a representative sample for the study, Yamane's (1973) formula  $(n = N / 1 + N(e)^2)$  was used to calculate the household sample size, where  $n$  represents the sample size, the population size is  $N$ , and the 95% confidence level, and level of precision ( $e$ ) is 5%. The sample size was

calculated based on the overall number of households within each local municipality. The total sample size consisted of 400 households (Table 4.2).

**Table 4.2** Sample size.

<b>Elevation Zone</b>	<b>Local Municipalities in the Zone</b>	<b>Population size</b>	<b>Number of Households</b>	<b>Sample size</b>
High Elevation	Phumelela	50 054	14 586	33
	Maluti-a-Phofung	353 453	110 725	247
Low Elevation	Setsoto	117 361	37 246	83
	Mantsopa	53 525	16 951	38
<b>Total</b>		574 393	179508	400

#### 4.4.3 Data analysis

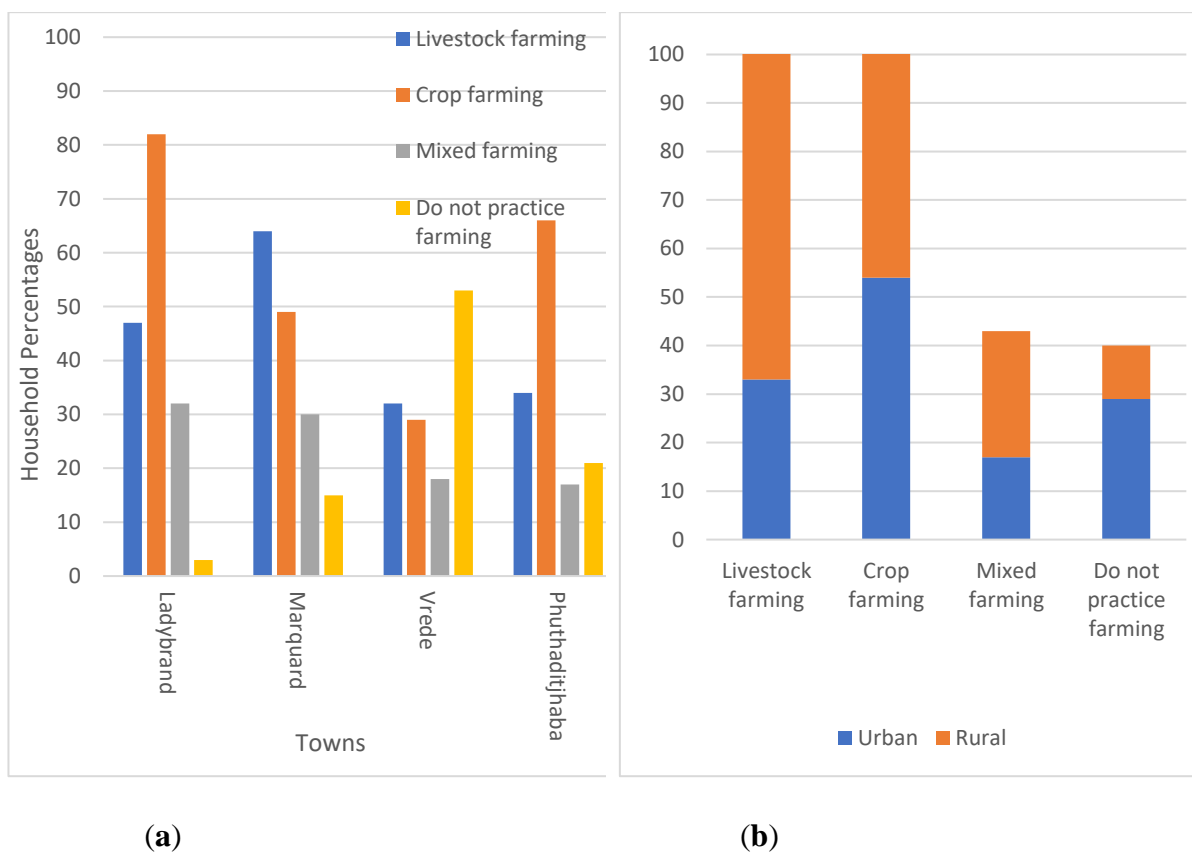
Data from the questionnaire survey were captured, processed, and statistically analysed for descriptive statistics (frequencies and percentages) by coding the responses of respondents to different closed-ended questions. The analysis was done in Microsoft Excel 2016 and SPSS (Version 17.0) environments. The Pearson Correlation and logistic regression were used for statistical analysis. Prior to conducting the analysis, data were tested for normality using the Kolmogorov-Smirnov test to determine if the data were parametric or non-parametric (Orcan , 2020). Logistic regression was used. The bivariate correlation was applied before running the logistic regression which determined whether any relationship existed across the variables being examined. Thematic analyses were conducted to organize the data gathered from the interviews to themes (Mkonda and He, 2018). The analysed data were presented in graphical and tabular formats.

## 4.5 Results

### 4.5.1 Eastern Free State Region Livelihood Strategies

Diverse livelihood strategies of households were identified across the study area. The findings show that communities in the study site contribute to livelihood activities such as cultivation, livestock grazing, mixed farming, as well as participating in non-farm activities. The results show that a significant fraction (78 %) of the respondents in the region rely on livestock and crop farming as part of their livelihood strategies. Even though it is a small fraction, 22 % of

the respondents solely depends on non-agricultural livelihood strategies like petty trade (selling clothing, food, and crafts); employment from the government and private companies; and self-employment—leasing rooms, welding, painting, building, tailoring, mechanical trades, brickmaking, and carpentry. With 78% of the households depending on livestock and crop farming, a large proportion of the population is exposed to climate change because their livelihood strategies are dependent on prevailing climatic conditions. Figure 4.4 summarises the percentages of respondents engaged in on-farm activities and those who do not practice farming.



**Figure 4.4** Summary of the percentages of respondents engaged in the stated livelihood activities (a) across the sampled towns (b) in urban (n=214) and rural (n=186) areas.

In the EFSR, livelihood activities were similar across the sampled towns, whereby most households in urban and rural areas derive much of their food from backyard gardening and small-scale farming. Some respondents stated that their livelihoods are based on the income they earn from selling the vegetables they grow in the backyard. Some households grew the vegetables only for household consumption or subsistence purposes. Dependence on on-farm products for food was reported by many rural and non-rural households in the EFSR. However, some households stated that they were not food self-sufficient.

#### *4.5.2 Households' Perceptions of Climate Change and Variability*

Results from the survey data, indicate that local households acknowledged changes in the temperature and precipitation patterns and occurrence of natural hazards (floods, droughts, and stormy winds). Overall, out of the 400 households that were included in the survey, 74.5% reported an increase in summer temperatures, 14.5% noted a decrease in maximum temperatures, while 11% respondents reported no change in average summer temperatures. Most respondents said that the winter season was becoming colder, with more than 50% of the respondents reporting a decrease in minimum temperatures. A small percentage of respondents in Ladybrand (29 %), Marquard (21 %), Phuthaditjhaba (18 %) and Vrede (24 %) reported that the winter season was becoming warmer. Among the household members interviewed in the EFSR, 207 (51.75 %), respondents agreed that the average rains have declined over the years. While 151 (37.75 %) of the households reported an increase in rainfall, 42 (10.5 %) of the households observed no change. In descending order of severity of impact, the events of natural disasters were perceived as droughts 325 (81 %), strong winds 176 (44 %), floods 127 (32 %), hail 40 (10 %), snow 32 (8 %), and lightning 23 (6 %).

#### *4.5.3. Perceived Impacts of Climate Change and Variability on Livelihoods.*

The data from the questionnaire survey was used to assess climate change impacts on the rural and urban livelihoods of the local communities in the region. The results show that climate change significant impacts the livelihoods of mountain communities in the EFSR. The respondents reported that mountain households in the region are increasingly becoming more exposed to climate-related hazards. Respondents from Ladybrand (92 %), Marquard (88 %), Vrede (70 %) and Phuthaditjhaba (94 %) indicated that climate change and variability impact their natural resource-based livelihoods, and socio-economic systems. Only thirty-eight respondents (9.5 %) reported no effects of climate change and natural disasters on their livelihoods.

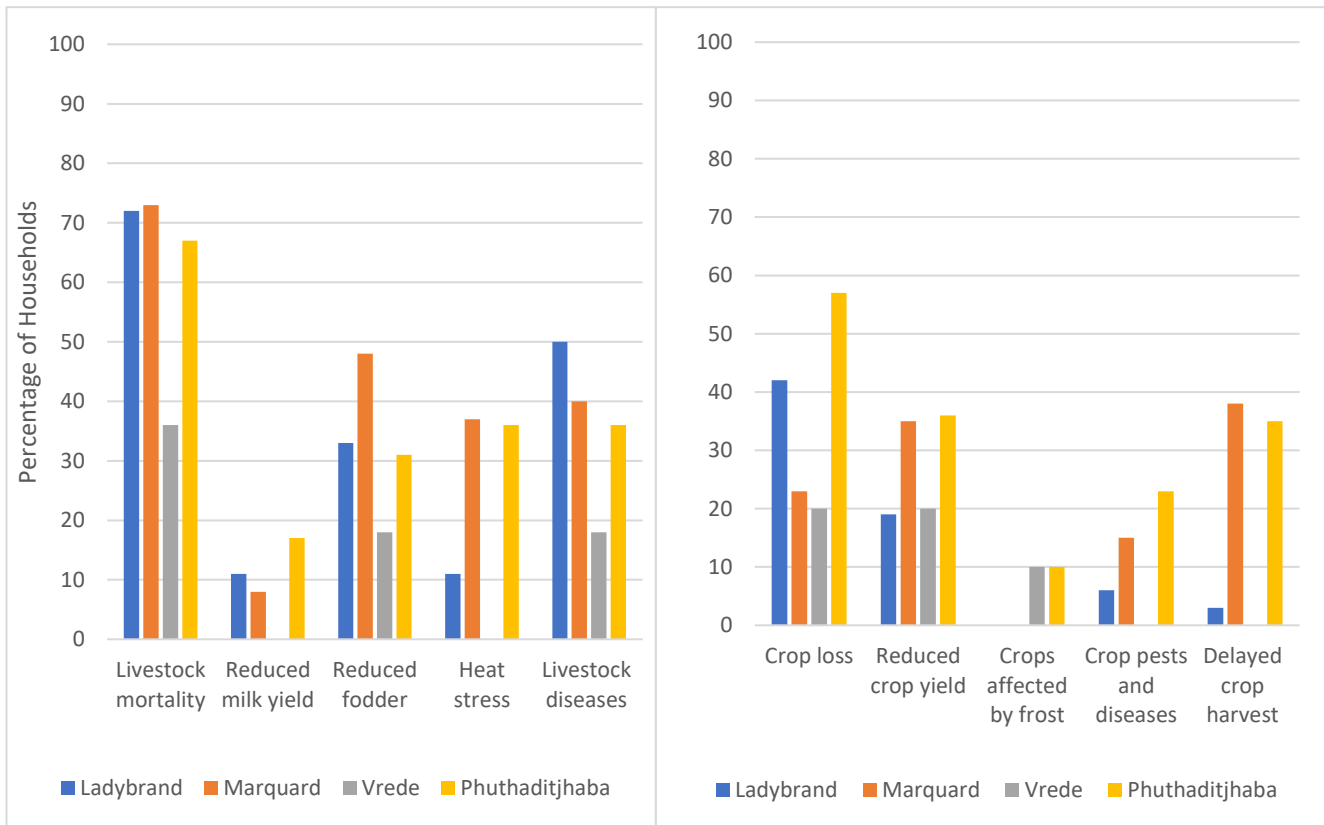
According to Singh et al. (2020), risk perceptions of rural communities often vary according to their resource endowments and the local agroecological conditions. The results show that, despite the similar views held about households experiencing climate change and variability, as well as occurrence of climate hazards, experiences of climatic impacts on livelihoods amongst the respondents might have differed due to the nature of livelihood strategies they practiced and the nature of settlements (urban and rural) in which they lived. The livelihoods of local communities in rural areas are largely climate-dependent, hence these communities are likely to notice any slightest climate related changes that affect the on-farm activities that they

rely on for livelihood. In urban settings, climate change has a much less impact on residents' daily livelihood needs because there is a greater diversity of livelihood opportunities, especially those derived from non-farm activities.

For instance, a higher percentage of households residing in urban areas do not practice farming (Figure 4.4), hence it is likely that their perceptions were based mainly on the impacts of climate change on off-farm activities, while in rural areas on-farm activities are the mainstay of livelihoods. Hence, it is most likely that their perceptions are more influenced by impacts of climate change on on-farm activities than off-farm activities. The results also show that subsistence farming (crop and livestock farming) in the rural parts of the district tends to be more vulnerable to climate change than subsistence farming in this region's urban areas. This is because livelihoods in rural areas are more susceptible to climate change as opposed to urban areas since livelihoods in urban areas are more diversified. As explained below, the rural-based households choices to diversify into non-farm activities are constrained due to limited opportunities and resources, hence they face higher risks from climate change.

#### *Climate Change and Livestock Farming*

Across the EFSR, livestock dependent households mentioned cases of climate-induced impacts on livestock farming (Figure 4.5), namely, livestock diseases, reduced fodder, heat stress, livestock death and injury related to natural disasters. In the district, erratic rainfall and drought events have caused limited water accessibility, availability, and supply for the livestock-based communities, resulting in water bodies drying up, impeding water access for the livestock and livestock-based activities. Figure 4.5 presents the results on climate change implications on crop and livestock farming in the high elevation zone (Phuthaditjhaba and Vrede) and low elevation zone (Ladybrand and Marquard).



**Figure 4.5** Percentages of perceived impacts of climate change impacts on (a) livestock farming and (b) crop farming in the EFSR.

Reduced livestock fodder was also noticed by the households that were involved in livestock keeping, with 33% reporting it in Ladybrand, 48% in Marquard, 18% in Vrede and 31% in Phuthaditjhaba. The respondents explained that erratic rains, delayed onset of rain, persistent years of droughts and high temperatures had caused poor growth in pastures, leading to changes in the availability and quality of the pastures. This is confirmed by the significant correlation between perceptions of rainfall and livestock fodder ( $p < 0.05$ ). Some of the respondents said there was no moisture on the grass compared to the past years, causing the grass in winter to become dry and unpalatable for the livestock. The perceptions seem to correspond with those reported by Gobena et al. (2022), who noted that low rainfall affects the palatability of grass species and leads to shortages in the variety and quality of livestock fodder. Consequently, a shortage of feed due to late onset of rains was reported as one of the causes of livestock deaths due to starvation, as respondents could not afford to buy supplementary livestock feed. Research findings from households in Monduli District, Tanzania, perceived less fodder and animal starvation that resulted in death due to reduced rainfall and droughts (Kimaro et al. 2018). In this study, respondents from the four towns shared similar experiences of fodder

shortages due to climate change. One of the respondents from Qwaqwa villages said, "It is difficult to find fodder for my livestock in the forests due to drought events." Another respondent from Qwaqwa said, "Grass in winter is now dry because of no moisture. In the past, there used to be snow or fog on the grass that benefited the livestock." Another said, "I used to let my cows graze in the fields, but now they are always in the kraal because there is limited pasture." "I used to give my livestock feeds once a day, but now I have to provide feeds to the livestock three times a day, because they cannot go to graze due to poor pastures." "I used to cut more fodder and keep it for winter, but now I am not able to harvest fodder during summer due to low forage related to droughts."

Furthermore, shortages of fodder and low water availability resulted in reduced milk yields. A small fraction of the respondents from Ladybrand (11 %), Marquard (8 %), and Phuthaditjhaba (17 %) reported reduced milk yields due to climate change. This might indicate that among the interviewed households, few respondents keep dairy cows. Some respondents have previously raised dairy cows but abandoned dairy farming due to shortages of water and stock feeds, thus opting for non-dairy breeds that are more tolerant to unpredictable environmental changes. Some households that depended on livestock for livelihood might have been unaware of the negative effects of hot conditions on lactating dairy cows.

One of the perceived climate indicators was increased summer temperatures. The respondents in all towns except Vrede reported that hot environments have resulted in livestock experiencing heat stress, with Ladybrand (11 %), Marquard (37 %), and Phuthaditjhaba (36 %) reporting climate-related heat stress in livestock. The respondents demonstrated the following: panting of livestock; livestock sweating; reduced feed intake and increased water intake during the day; and livestock changing the way they walk as signs related to heat stress-induced by high temperatures. At the same time, perceived decreasing minimum temperatures were reported to result in livestock sickness. Moreover, it is probable that none of the respondents from Vrede reported climate-related heat stress on livestock farming. The livestock-based respondents who reported no climate-related heat stress impacts stated that when it is hot, the livestock look for shade and the livestock are not affected by the hot environment.

Most of the surveyed households reported that they received heavy rains in the past two years (2020 and 2021), mostly during the JFM months. The respondents reported that heavy rains occurring in consecutive days have resulted in livestock diseases. All the respondents who reported incidents of livestock diseases due to flooding said that heavy rains create water-

logged conditions which result in most livestock getting stuck in mud, causing injuries and/or death. The respondents in Ladybrand (50 %), Marquard (40 %), Vrede (18 %) and Phuthaditjhaba (36 %) reported increased incidents of livestock diseases related to heavy rains. The results show a higher percentage of the households in low elevation zone who reported livestock diseases related to heavy rains compared to households in high elevation zone. This variation might be a result of poor soil drainage in the low elevation zone, which resulted in waterlogging, unlike in steeply inclined high elevation areas which are characterized by high surface runoff and low waterlogging. In Marquard, one of the respondents said, "I used to inject my livestock two times a year, but now they easily get sick and need more injections due to heavy rains." Similar studies have been reported about high livestock diseases and mortality related to heavy rains or floods (Lacetera 2019). In Nkombose, Ebaswazini, and Ogengele areas of the Mtubatuba Local Municipality (Kwa-Zulu Natal Province of South Africa), droughts resulted in increased livestock deaths (Sibiya, 2019).

In the 2021 season, nevertheless, some respondents profited from the heavy rains that occurred. Examples include some respondents who were interviewed in Ladybrand who reported that livestock fodder was available even during the winter season due to heavy rains that year. With regard to the drought years, some livestock-based households reported that low ground cover and shortages of pasture caused by insufficient rain induced events of overgrazing. Consequently, the exposed surface exacerbated erosion of veld and agricultural lands.

The risks of climate change impacts on animals were perceived differently among the respondents in the high and low elevation sites and within the same elevation sites. According to Stäubli et al. (2018), the effects of these threats on mountainous communities differ based on their level of vulnerability and exposure. The respondents held different views about livestock mortality, including those related to shortages of fodder, inability to purchase vaccinations and supplementary feeds and the effects of heavy rains. Sixty-seven percent of the respondents from Phuthaditjhaba, 36% from Vrede, 73% from Ladybrand and 72% from Marquard all reported livestock mortality related to the above-mentioned climate-related effects. For instance, two respondents in Marquard said they used to keep livestock, but the cows got stuck in the mud and died due to heavy rains. Another respondent said, "Heavy rain affected my livestock as a number of the livestock died because they were trapped in the mud." Taking the case of Qwaqwa as an example, households reported that they used to have cows, but lost them due to drought induced low feed availability. Respondents from Ladybrand,

reported incidents of water-borne livestock diseases and livestock deaths due to poor water quality. Variations in what has been reported about the impacts of climate change indicate the diversity of environmental and socio-economic conditions prevailing in local communities across the region. This calls for the need to design context-specific livelihood strategies in order to adapt to climate change.

#### *Climate Change and Water Availability and Quality.*

The study examined perceptions about the influence of climate variability on water availability and quality in the local communities of the EFSR. Among the household members surveyed in the region, 51.75% of the respondents observed that the average summer rains have declined over the years. Evidence from the survey shows that drying surface water bodies reduced the capacity to supply water to the local communities, consequently affecting local livelihoods in the region. More than 50% of the respondents in all representative towns revealed low water quantity and quality related to climatic events. Most of the households from the region in Ladybrand (68 %), Marquard (62 %), Vrede (59 %), and Phuthaditjhaba (70 %), acknowledged that the quantity and the quality of water have deteriorated due to erratic rainfall, heavy rainfall, droughts, and increased temperatures. This is confirmed by the significant correlation between perceptions of drought and floods and changes in water quality and quantity ( $p < 0.05$ ). According to Mohamed and Mukwada (2019), rising temperatures will increase evapotranspiration from water bodies (wetlands, rivers, water reservoirs) and reduce water supply to local communities. Due to water scarcity, households that depend on on-farm activities do not only experience shortages of water for domestic purposes, but also experience low crop yields and high livestock fatalities, leading to low on-farm income and increased food related expenditures. However, some respondents from Ladybrand (32 %), Marquard (38 %), Vrede (41 %), and Phuthaditjhaba (30 %), did not report water shortages. This might indicate that the respondents who did not report water scarcity might have been from homes that had more than one source of water, such that they were not affected to the same degree as other households. This means that access to more than one source of water is more likely to reduce climate change vulnerability among local communities. Therefore, it is crucial for households in local communities to receive support from the government regarding the diversification of water sources to enable them to deal with the impacts of climate change.

Most households in the EFSR were convinced that the fluctuations in average summer rainfall have led to drought events in recent years. The perceptions held by households of increased

temperatures and low rainfall have highlighted the region's sensitivity to drought events. For example, one of the respondents from Vrede reported that the Emanzini Dam dried up due to the drought that occurred in 2015, leading to shortage of water for the whole Vrede community. The respondents from high elevation (Phuthaditjhaba) and from low elevation (Ladybrand and Marquard) reported that water scarcity had led to water shortages for their livestock. However, in Vrede, respondents ten (29 %) who rear livestock did not report water shortages for their livestock. On the other hand, three respondents from Ladybrand reported that water scarcity in their area had led to their livestock using unsafe water sources, resulting in illnesses. Similar studies have described cases showing how climate change and variability had implications for water availability, thus compromising household activities such as cooking, gardening, and laundry (Bedeke et al. 2019; Lottering, Mafongoya, and Lottering 2021).

#### *Climate change and Crop farming*

In the current study, households were surveyed to determine if climate change was affecting crop-based livelihoods. The results revealed that households that depend on backyard gardening as their main source of subsistence faced problems such as crop loss, low crop yields, and crop destruction caused by reduced rainfall, erratic rainfall, delayed onset of rainfall, and natural disasters (Figure 4.5). This is confirmed by the significant correlation between perceptions of droughts, reduced rainfall and floods and crop production ( $p < 0.05$ ). Some respondents either reduced the variety of crops they grew or left crop farming due to low rainfall or droughts. For example, thirteen respondents from Phuthaditjhaba reported that they used to do backyard farming, but because of recurrent droughts, they had to quit. Similar findings came from Ladybrand (six) and Marquard (five) urban areas where respondents abandoned gardening due to water shortages, increased summer temperatures and low rainfall. The respondents from Phuthaditjhaba and Ladybrand described stunted growth, wilting of leaves, and low crop yield due to low rainfall. Similar findings were reported from Semien Mountains, Northwest Ethiopia, where climate change reduced the productivity of farms in some communities and damaged farms' potential, leading to the abandonment of crop farming activities due to low outputs (Yohannes, Teshome, and Belay 2020). According to Ghosh and Ghosal (2020), small changes in daily weather phenomena like humidity and temperature result in significant changes in agricultural production and everyday economic activities.

In the EFSR local households reported reduced crop yields due to the occurrence of climate hazards related to hailstorms, erosion of agricultural lands, heavy rains, droughts, and frost.

Respondents reported crop destruction due to heavy rains in Vrede (30 %), Phuthaditjhaba (71 %) Ladybrand (50 %) and Marquard (40 %). The respondents noted that the waterlogging resulting from flooding led to crops rotting. The respondents from Vrede and Phuthaditjhaba said that when incessant rains fall crops like pumpkin and tomatoes die due to excessive water supply. Similar agrarian impacts of climate change and variability have been found in other studies (Qaisrani et al. 2018; Lottering, Mafongoya, and Lottering 2021). The livelihood implications of this are many and multifaceted. It should be noted that any adverse impacts of climate change have significant implications for people's access to food (Chersich and Wright, 2019).

Overall, the results of the current study indicate that climate variability has resulted in crop loss, reduced crop yields and has accelerated the loss of on-farm income. Respondents reported crop loss due to erratic rainfall and increased temperatures in Vrede (20 %), Phuthaditjhaba (57 %) Ladybrand (42 %) and Marquard (23 %). Respondents also reported cases of reduced crop yields from Vrede (20 %), Phuthaditjhaba (36 %), Ladybrand (19 %) and Marquard (35 %). For example, in Ladybrand, only four respondents said they used to plant large quantities of crops, but due to irregular and erratic rainfall, the crop yields have reduced, eroding our on-farm income. Five respondents from Qwaqwa reported that they used to sell their vegetables. However, the quantity has reduced and now the vegetables grown are mainly for household consumption. Two participants from Marquard stated that they used to have more vegetables to sell, but the quantity of their crops has recently decreased, resulting in a lower income. This was also reported in previous studies on climate change impacts on cash crops that have hampered households' on-farm income (Abebe 2021; Jalal et al. 2021). According to Drysdale et al. (2020), reduced food production will limit food availability and trigger an increase of food prices, impacting access to food.

The respondents who stated that they stopped growing vegetables due to erratic rains, do not solely depend on on-farm for livelihood upkeep. However, those who reported that their livelihoods relied on growing vegetables noted that they grew vegetables in all seasons of the year, despite the harsh conditions they were experiencing, because market gardening is their primary source of income. Most households have stopped practicing winter cropping due to increasing water shortages and **frost attack**. However, in Qwaqwa, respondents from some rural villages reported that they still practiced winter cropping, which is their major source of income, while in the urban area the respondents said they no longer practiced winter cropping due to the worsening of cold weather. This indicates that the main activities practiced by the

local communities and sources of household income play an important role on how households respond to the impacts of climate change on crop farming. It is for this reason that we should focus on the development of more advanced adaptation strategies to aid the livelihoods of vulnerable communities.

### *Social Consequences of Climate Change*

The socio-economic impacts of climate change varied slightly across the two elevation zones. The respondents perceived the main socio-economic climate change-related to be loss of income, health problems, labour, loss of employment, and additional expenses. However, only 25 respondents stated that they faced climate-related health problems. Children and old aged household members were the most vulnerable individuals reported in the study. Cold weather, dusty winds, and heatwaves from high summer temperatures are some of the climate indicators that have been reported to cause health problems as reported from Ladybrand (3), Marquard (4), Phuthaditjhaba (16) and Vrede (3). Some of the respondents from Qwaqwa reported that the low-quality water and low water availability resulted in poor hygiene and sanitation. This is supported by a study in Nepal that reported cases of low water quality related to climate-induced water scarcity, leading to deteriorating human health (Mishra, Hussain, and Rasul 2016). Other studies in Mogalakwena and Ga-Dikgale districts of the Limpopo Province of South Africa have reported similar impacts, including the spread of diseases such as cholera, bilharzia, and dysentery due to reliance on contaminated water as a result of severe water shortages (Rankoana, 2016; Chikosi et al., 2018).

Cold weather and dusty winds have also lowered the efficiency of household labour. Although the respondents perceived an increase in average summer temperatures, the respondents reported no effect of heat stress on health or labour-related issues. Most respondents who work outdoors said they were now used to the hot environment, hence the heat during the day did not affect their work efficiency. Some respondents who practiced agriculture in Ladybrand and Vrede said they preferred to work during the summer when it is hot compared to the cold winter season. The results of this study differ with those from a study carried out in India where respondents reported the significant effect of high temperatures on people's health and the inefficiency of labourers in the fields (Brown et al. 2019).

A few respondents who work on farms or practice agriculture as a source of income reported reduced work efficiency due to cold weather. For example, "During the winter, I cannot work in the early hours of the day because my hands are frostbitten, and the water pipes are frozen;

we have to wait for the weather to warm up. However, waiting for the morning temperatures to be warmer delays harvesting and sale of the vegetables”, said the respondent from Vrede. On the contrary, some of the respondents in Marquard who work on farms said, that they go to work in the morning even when it is cold because they have no other alternative; “we need the money to sustain our families.” This could indicate that some households are compelled to rely on their labour as a source of income despite the harsh weather due to unavailability of alternative sources of livelihood.

The respondents have reported increased workload as a result of scarce resources, such as livestock fodder and water due to climate change. The respondents stated that water shortages have placed an additional burden on them because they now have to travel great distances to get water for household consumption, as well as for their livestock, crops, and off-farm activities such as brickmaking. For example, several respondents from Qwaqwa villages stated that they walk long distances to fetch water. Most respondents from the Qwaqwa sites reported similar experiences. "I used to get water from the tap, but now I have to collect water from the community storage tank during the day and sometimes at midnight." "My livestock used to drink from the river, but now, because of the drought, I have to deliver water to the mountains where the livestock are kept." Another respondent who did brickmaking pointed out that: "I used to use water from the river to do my bricks and water my crops, but now I collect water from JoJo tanks." "Fetching water was simple, but now it has become our daily activity, and we travel miles to fetch it." "I used to use tap water to water my crops, but now I have to fetch water using a wheelbarrow. Such increased labour to collect water makes me want to stop doing gardening." Studies in Satkhira District, Bangladesh and Lawra District, Ghana, and Kenscoff and Goyavier, Haiti, reported that during dry seasons the local communities travelled greater distances to collect water (Abdulai, Ziemah, and Akaabre 2017; Staub et al. 2020). However, no respondents from the other three urban areas that were included in the study reported increased labour due to water shortages,

#### *Economic Consequences of Climate Change*

Some of the households reported a loss of on-farm employment due to climate change. For example, one household member from Marquard said, "I had to change work in the last two years because our farm had to re-trench people because of recent droughts." Depending on the status of employment, some respondents said there were few temporary jobs available during winter. A male respondent from Qwaqwa reported reduced on-farm income due to the rains

that made it difficult to harvest the firewood and sell. This male respondent further stated that even when he harvests the firewood during dry days, the place where he kept the wood would become wet during the rainy season, and people do not buy wet wood. Despite increased rains impacting rural livelihoods negatively, some respondents reported a positive impact of heavy rains. For instance, one of the on-farm temporarily employed respondents from Phuthaditjhaba stated that because of heavy rains during 2020-2021, the lawn grew fast; hence I had to frequently come and cut grass, receiving more income compared to previous dry years."

Different respondents from the study area elaborated on the additional costs they experienced due to unpredicted changes in climate. Additional costs included buying more supplementary feed to cover for delayed regeneration of pastures due to delayed or low rainfall, buying water for drinking because of water shortages, and buying more firewood or gas to provide warmth during cold weather. Some respondents reported that they were now incurring additional expenses on livestock feed because of the delayed onset of the rainfall, making livestock farming more expensive. One respondent from Ladybrand reported that the delayed rainfall onset, was making livestock holding costly because farmers were forced to purchase supplementary feeds in order to keep livestock alive. Some respondents from Ladybrand reported that due to water shortages their livestock now depended on contaminated water, rendering them prone to worm infestation, thus increasing costs of disease control. Overall, the increased cost of agricultural production in an environment where agricultural returns are decreasing is reducing household economic viability and livelihood sustainability, leading to the worsening of poverty.

The respondents stated that the winter seasons have become colder, and the cold weather ends late, resulting in more expenses to provide warmth during winter. The respondents from Ladybrand 7 (18 %), Marquard 24 (30 %), Phuthaditjhaba 65 (26 %) and Vrede 2 (6 %) reported that they now spent more money to keep themselves warm compared to the past years because the winter temperatures have dropped. According to Moeletsi, Tongwane, and Tsubo (2016), low temperatures cause an early onset of frost and a late cessation of frost risks over the east and south-eastern parts of the EFSR. This is confirmed by a study done in Phuthaditjhaba, Qwaqwa, where the communities reported very cold weather conditions during winter (Melore and Nel 2020). Most respondents reported that during the winter they spent more money on firewood and gas to provide warmth.

A small proportion of the respondents who practiced off-farm activities reported that climate change impacted their off-farm activities. The cold and dusty winds blowing in June and July affect their daily schedule of livelihood activities. Strong winds and heavy rains interrupted their business activities, resulting in low income. Some rural households found it increasingly difficult to work outdoors under such climatic conditions. For instance, one of the respondents from Qwaqwa village said, "Sometimes I go door-to-door selling my items, so when it is cold and rainy, it is not easy to walk in muddy areas." A female respondent from Phuthaditjhaba who practiced off-farm activity stated she used to provide outdoor catering services. The respondent reported that unpredictable dusty winds and incessant rains impeded her business and reduced her household's income. Another female respondent who depended on petty trade for livelihood reported that she now had fewer customers in winter months because the weather had become colder. Another respondent said that due to the low quantity and quality of water available, he could no longer sell cooked food to his customers because of health and hygiene related reasons. From the above reports, it can be inferred that the reduced availability of water caused by climate change is affecting household income and sustenance. For example, a female respondent from Phuthaditjhaba reported that her hair salon was receiving only a few customers due to water shortages, hence her business was generating low income. Similar observations were reported in the Mtubatuba Local Municipality of Kwa-Zulu Natal Province (Sibiya, 2019).

#### *Climate change and Infrastructure*

The findings of the study show that 26 % and 32 % households from Ladybrand and Marquard respectively, and 3 % and 26 % households from Vrede and Phuthaditjhaba, reported disruption of essential services (communication, networks, electricity) by flood events. Khayyam and Noureen (2020) state that floods damage households and possessions and disrupt productive land, human settlement, drainage systems and other structures lying within the floodplain. The disruption of essential services due to heavy rains and lightning results in disruption of communication services and electricity supply, leading to inefficiency of businesses. A small proportion of the respondents from the study sites (7 %) reported road damage due to floods. Bursting of drainage pipes in winter due to frost was recorded by some of the respondents from Ladybrand (5 %), Marquard (12 %), Phuthaditjhaba (10 %) and one respondent from Vrede (3 %). The respondents mentioned additional costs incurred in replacing the damaged pipes.

A significant number of respondents, 360 (90 %), own brick-walled houses, while 41 respondents (10 %) and 14 (4 %) live in shacks and mud-houses, respectively. However, fewer respondents reported that their houses had been damaged by floods, 37 % in Ladybrand, 10 % in Marquard, and 24 % in Phuthaditjhaba. Due to the poor quality of shelter they live in, shack dwellers reported flooding in the areas in which they live, which often leads to loss of property. Similarly, some respondents who live in mud houses reported erosion of their houses by heavy rains, thus rendering their properties vulnerable to climate change. It is logical assuming that poor housing quality in rural areas, where most people live in mud houses and shacks, makes the rural population more vulnerable to heavy rains and strong winds, compared to urban areas, where people live in brick walled houses. In a study conducted in Pakistan, Qaisrani et al. (2018) have observed that about 50% of households in D.G Khan, are susceptible to destruction by climate hazards because they live in mud or thatch houses. According to Qaisrani et al. (2018), the type of housing structures in an area determines the susceptibility of households to climate change impacts. Other respondents reported blowing off or leakage of roofs due to strong winds and heavy rains.

As mentioned above, some of the respondents reported that they had not been impacted by climate change and variability. This can be attributed to the type of livelihood activities which their households depend on. For example, one of the respondents from rural villages of Qwaqwa stated: "We have never experienced water crises. Hence, changes in the climate do not affect us." Another surveyed respondent from Phuthaditjhaba said, "Weather does not disturb my activities as I use my vehicle to work, and I work inside the building." One male from Marquard reported: "Changes in the climate do not affect me as I am a truck driver. I travel most of the time." One respondent from urban areas in Marquard said, "Temperature and precipitation have changed, but we have never experienced any climate-related impacts."

In addition to climate related hazards, some households mentioned other non-climatic factors that affect their on-farm livelihoods. For example, some of the respondents in Vrede stated that they face problems with birds and rats that feed on their crops. In Marquard, some respondents reported the unavailability of additional land for livestock farming. In Ladybrand and Qwaqwa, theft was one of the main reasons some households kept a small number of livestock or even stopped practicing livestock farming altogether. Understanding how these multiple stressors, including climate change, interact to affect livelihoods is vital for developing adaptation strategies (Singh et al. 2020).

#### 4.6 The Logistic regression model results

Before the logistic regression was performed, bivariate correlations were used to evaluate the connections between the explanatory variables. The findings of the correlations showed some connections between the explanatory variables such as floods, droughts, hail, elevation, crop loss, livestock diseases, and reduced livestock fodder. The logistic regression results of respondents' perceptions in urban areas are presented in Table 4.3, showing the level of significance, standard errors, regression coefficient ( $\beta$ ), and odds ratios (Exp (B)).

**Table 4.3** Binary logistic regression analysis findings of respondents' perceptions in urban areas.

Dependent variable	Independent variable	B	S.E.	Wald	Sig.	Exp(B)
Increased crop pests and diseases	Changes in precipitation	-2.456	1.136	4.677	.031	.086
	Strong winds	-3.451	1.103	9.791	.002	.032
	Constant	.723	.965	.562	.453	2.061
Crop Loss	Droughts	-.961	.790	1.478	.224	.383
	Elevation	-1.138	.472	5.801	.016	.321
	Constant	.812	.357	5.169	.023	2.253
Heat Stress	Elevation	-2.361	1.111	4.516	.034	.094
	Floods	1.106	.875	1.598	.206	3.021
	Strong winds	1.390	.795	3.059	.080	4.015
	Constant	-.171	1.447	.014	.906	.843
Reduced livestock fodder	Elevation	-2.06801	1.00779	4.21073	0.04016	0.12643
	Floods	0.11776	1.02371	0.01323	0.90841	1.12498
	Strong winds	1.84545	0.91184	4.09604	0.04298	6.33095
	Constant	-19.5194	6493.85	9.03E-06	0.99760	3.33E-09
Increased livestock diseases	Floods	1.388	.742	3.500	.061	4.006
	Strong winds	1.722	.619	7.743	.005	5.597

	Constant	-2.448	.618	15.683	.000	.086
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Out of the selected explanatory variables, such as elevation and strong winds were shown to have a significant ( $p < 0.05$ ) impact on reduced livestock fodder. According to the regression analysis, variables such as floods and strong winds increase the probability of households' perceiving heat stress in livestock, reduced livestock fodder, and livestock diseases in urban areas. For each level increase in floods, the likelihood that the respondents in urban areas perceive incidents of livestock diseases due to floods (as opposed to not being aware) increased approximately by 1.388. The results show that a negative coefficient (-2.456 and -3.451) implies a decrease in the likelihood of perceived increased crop pests and diseases for every unit increase in precipitation and strong winds. In contrast, changes in precipitation and strong winds are less likely to cause increased crop pests and diseases and crop loss.

The logistic regression results of respondents' perceptions in rural areas are presented in Tables 4.4 and 4.5, showing the level of significance, regression coefficient ( $\beta$ ), odds ratios (Exp (B)) and standard errors.

**Table 4.4** Logistic regression analysis results of respondents' perceptions in rural areas.

Dependent variable	Independent variable	B	S.E.	Wald	Sig.	Exp(B)
Crop destruction by natural disasters	Floods	1.073	.616	3.034	.082	2.925
	Droughts	2.461	.639	14.830	.000	11.721
	Strong winds	1.014	.580	3.061	.080	2.757
	Snow	-.223	.787	.080	.777	.800
	Constant	-2.071	.627	10.907	.001	.126
Crop Loss	Changes in Tmin	-1.461	.444	10.852	.001	.232
	Changes in precipitation	.101	.493	.042	.837	1.107
	Floods	3.462	.887	15.244	.000	31.884
	Droughts	2.521	.883	8.146	.004	12.442
	Strong winds	-1.264	.828	2.333	.127	.282
	hail	.035	.810	.002	.965	1.036
	Snow	.491	.906	.294	.588	1.634
	Constant	-.512	1.419	.130	.718	.599

Reduced crop yield	Changes in Tmin	-.863	.372	5.378	.020	.422
	Floods	1.867	.728	6.582	.010	6.467
	Droughts	2.405	.802	8.991	.003	11.075
	Strong winds	-.916	.739	1.536	.215	.400
	hail	.443	.612	.523	.469	1.557
	Snow	.488	.652	.561	.454	1.630
	Constant	-1.065	1.036	1.056	.304	.345
Increased crop pests and diseases	Changes in Tmax	1.345	0.635	4.494	0.034	3.839
	Changes in Tmin	-1.585	0.781	4.117	0.042	0.205
	Changes in precipitation	-0.232	0.537	0.187	0.665	0.793
	Floods	19.262	5738.424	0	0.997	2.32E+08
	Droughts	35.918	8777.099	0	0.997	3.97E+15
	Strong winds	-16.126	5738.424	0	0.998	0
	hail	-0.464	0.781	0.354	0.552	0.628
	Snow	0.189	0.783	0.058	0.809	1.208
	Constant	-36.935	8777.099	0	0.997	0

(N=114)

From the regression results, in rural areas, the independent variables such as floods and droughts are most likely to result in crop loss, reduced crop yield, and crop destruction. These findings show that communities in rural settings are more likely to perceive floods and droughts as climate-related impacts on crop farming.

**Table 4.5** Logistic regression analysis results of respondents' perceptions in rural areas.

Dependent variable	Independent variable	B	S.E.	Wald	Sig.	Exp(B)
Reduced milk yield	Floods	.740	.834	.787	.375	2.097
	Strong winds	.722	.874	.683	.408	2.059

	hail	.885	.724	1.494	.222	2.424
	Snow	.902	.769	1.374	.241	2.464
	Constant	-3.032	.634	22.902	.000	.048
Reduced livestock fodder	Elevation	-.548	.590	.865	.352	.578
	Changes in Tmin	-1.712	.614	7.777	.005	.180
	Droughts	2.527	1.242	4.139	.042	12.519
	Constant	-.025	1.571	.000	.987	.975
Heat stress	Floods	1.137	.653	3.034	.082	3.118
	Droughts	1.745	.825	4.472	.034	5.724
	Strong winds	.589	.623	.894	.345	1.801
	hail	.921	.770	1.429	.232	2.512
	Snow	.932	.831	1.257	.262	2.539
	Constant	-3.114	.830	14.083	.000	.044
Increased livestock diseases	Changes in Tmin	-1.214	.456	7.092	.008	.297
	Floods	1.334	.608	4.805	.028	3.795
	Strong winds	.487	.587	.689	.406	1.628
	hail	.503	.689	.533	.465	1.653
	Snow	.956	.821	1.356	.244	2.601
	Constant	.957	.907	1.112	.292	2.603

(N=95)

From the

regression results, there is a probability of floods affecting livestock diseases and heat stress in rural areas. The results show that a positive coefficient (2.527 and 1.745) implies an increase in the likelihood of perceived reduced livestock fodder and heat stress for every unit increase in drought events. Droughts have the highest probability of influencing livestock fodder, and heat stress in rural areas. The strong winds that are experienced during summer have the

probability of reducing livestock fodder availability and causing heat stress. The results (Tables 4.3 and 4.4) indicate that flood events increase the possibility of increased incidents of livestock diseases in urban and rural areas as the odds ratio is greater than one. However, the likelihood of perceived changes in minimum temperatures and elevation influencing livestock fodder is a negative coefficient (-0.548 and -1.712), indicating that changes in minimum temperatures and elevation were found not to influence respondents' perceptions of reduced livestock fodder. The odds ratio indicates that perceived changes in precipitation are less likely to cause increased crop pests and diseases and crop loss by a factor of 0.793 and 1.107.

#### **4.7 Conclusion**

The main objective of the paper was to examine the perceptions of local households in the EFSR of South Africa about the impacts of climate change on their livelihoods. Reduced water quantity and quality, crop loss, reduced crop yields, animal diseases, livestock mortality, and disruption of essential services were recognized as some of the negative environmental impacts of climate change and variability across the sampled sites. The respondents perceived the main socio-economic impacts of climate change to be loss of farm and non-farm income, increased labour, health problems, loss of employment and increased expenses on household commodities, as well as heating, and acquisition of supplementary feeds for livestock. As shown in the foregoing discussion, the livelihoods of the local households in the mountainous environment in the EFSR are supported by arable land and biodiversity as the main natural resources. The findings of this study indicate that livelihood activities differ slightly across the towns, thus reflecting the diversity of household livelihoods in the region. The most perceptible differences are discernible at regional level where two elevation zones are evident, namely the upper and lower elevation zones. However, in both elevation zones, most households have noticed increasing trends of summer temperatures and decreasing winter temperatures, decreasing precipitation, incidents of crop losses, reduced crop yields, incidents of livestock diseases and mortality, and damages to infrastructure. All these changes can be regarded as indicators of climate change. However, differences existed between the impacts of climate change in the upper and lower elevation zones of the region. Though increased livestock mortality and livestock diseases were reported in both zones, a greater number of respondents from the lower elevation zone were affected by these problems compared to the higher elevation zone. Differences also occurred regarding the way climate change impacted rural and urban communities. For instance, a higher proportion of respondents from rural areas reported

an increase in labour requirements due to water shortages compared to urban areas. Also, a small percentage of the households who were involved in off-farm activities perceived some climatic implications for their livelihood activities. The diverse climate change effects on on-farm and off-farm activities reported by households were contextualized according to households' primary livelihood activities and the settlement type. Since the perceptions of the households were examined based on self-reported response, the study has limitations. As such, the responses are likely to be biased, and because self-reported behaviour may not correspond to real behaviour. Hence, future research should analyse the households' actual behaviours.

**Author Contributions:** Conceptualization, G.M.; methodology, L.M and G.M.; validation, G.M.; formal analysis, L.M.; data curation, L.M.; writing of original draft, L.M.; writing—review and editing, G.M.; supervision, G.M.; project administration, G.M.; funding acquisition, G.M. The final manuscript has been approved for publication by all authors after reading it.

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## CHAPTER 5: AN EVALUATION OF THE EFFECTIVENESS OF ADAPTATION STRATEGIES IN ADDRESSING THE IMPACTS OF CLIMATE CHANGE ON LIVELIHOODS IN THE EASTERN FREE STATE REGION, SOUTH AFRICA

### 5.1 Brief chapter synopsis

This chapter is based on the paper which was submitted to *Cogent Social Sciences* as

**Msimanga Lokuthula\***, and **Mukwada Geoffrey. (2022)**. An evaluation of the effectiveness of adaptation strategies in addressing the impacts of climate change on livelihoods in the Eastern Free State Region, South Africa.

### 5.2 Abstract

Climate change has become a threat to rural mountain communities, directly affecting livelihoods. Communities have developed adaptation strategies to safeguard their livelihoods from the impact of climate change. However, there exists a dearth of knowledge on the effectiveness of adaptation strategies for reducing climate change vulnerability. The objective of this study was to identify the most preferred adaptation strategies for local communities in the Thabo Mofutsanyane District Municipality, South Africa. A household survey based on a multistage sampling technique was used to select 400 participants for interviewing using a semi-structured questionnaire. Data analyses were based on descriptive statistics, cross-tabulations, and the Student T-Test. Results indicated that, households had adopted a range of strategies, including new water measures and soil management practices, purchasing livestock feeds, dependence on drought-resistant livestock species, and different socio-economic measures. However, in this region, these adaptation initiatives may not be enough to lower socio-ecological vulnerability, due to lack of socio-economic and institutional support. Hence, institutional support from community-based adaptation programs and extension services are required for the design and implementation of effective climate change adaptation measures. Findings of this research can educate policy makers on measures to be considered for better climate adaptation in the region.

**Keywords:** Adaptation strategies, Climate change, Eastern Free State Region, Effective, Households, Livelihoods.

### 5.3 Introduction

Mechler et al. (2020) indicates that global climate change has a permanent impact on vulnerable communities and countries. Climate change and variability have an impact on communities' natural ecosystems and livelihoods (Kangalawe 2017). Furthermore, the irreversible nature of climate change significantly affects human and biological systems, undermines future ecosystem sustainability and livelihood security, as well as the well-being of present and future generations (Clarke et al. 2019). Several local studies in developing countries have acknowledged the adverse impacts of climate change on livelihoods and development (Dube et al. 2016; Thakur and Bajagain 2019; Cui and Feng 2020; Kogo et al. 2021; Staub et al. 2020).

In recent years, climate change adaptation has generated considerable attention with the awareness of global climate variation (Karki, Burton, and Mackey 2020). Piggott-McKellar et al. (2019) described climate change adaptation as adjusting to the existing or predicted climate and its impact. Adapting to climate change is necessary to ensure sustainable future agricultural productivity and rural livelihoods (Talanow et al. 2020). Globally, communities have been continuously coping and adapting to the changing weather, climate, and associated variations based on their knowledge, skills, experiences, and practices (Maharjan 2020). However, global adaptation assessments are rarely location-specific or relevant to the prevailing agro-ecosystem, and few explore what measures are needed to address system-specific threats (Brown et al. 2018). Although adaptation and mitigation strategies are crucial to alleviate climate change impacts in the short and long term, adaptation has become a localized strategy implemented at individual or group levels (Adzawla and Kane 2018). Different communities adapt differently to global change issues, such as climate change (Kangalawe 2017).

Several local communities have developed adaptation strategies to safeguard their livelihoods in response to the implications of climate change and variability. These include diversifying crops and varieties, changing planting dates, rotating crops, intensifying the use of irrigation, expanding farmlands, implementing different soil conservation mechanisms, and diversifying household income sources (Ombogoh et al. 2018; Currenti et al. 2019; Amfo and Ali 2020; Aryal et al. 2020; Saalu, Oriaso, and Gyampoh 2020). For instance, in Bangladesh, after extreme weather patterns, many households took loans, pursued additional income sources (sold labour, ran small shops for additional revenue), and sold livestock to repair their houses and recover from agricultural losses (Brown et al. 2018).

Many climate change adaptation studies undertaken in Africa have addressed multiple conditions that affect rural livelihoods, including food security, as well as access to energy, shelter, and income sources. An example is a study by Mabuku et al. (2019) which was carried out in Mwandia District, Zambia, which showed that most households adapted to floods by using short-term measures such as selling reeds, thatching grass, firewood, charcoal and wild food. Another example is a study on adaptation strategies implemented by the coffee-based communities in Fero-two Peasant Association in the Wensho District, in Southern Ethiopia, involving changing coffee cultivars and patterns and, the delaying of crop planting (Abebe 2020). The farmers also adopted new water and soil conservation methods such as building of small terraces, planting of elephant grass to stabilize slopes, soil mulching and covering of coffee plant roots to retain moisture, planting of trees and banana plants in-between coffee plants, as well as the construction of check-dams and terraces to prevent flooding (Abebe 2020). However, such traditional livelihood strategies are becoming less sustainable in some communities as new weather and climatic extremes emerge (Nembilwi et al. 2021). Kangalawe (2017) states that for these adaptation techniques to be successful, they must be built on existing livelihood strategies.

Dilling et al. (2019) argue that focus should extend to building and measuring capabilities that empower communities in the context of climate change instead of debating about climate change adaptation. Nembilwi et al. (2021) agree that studies have primarily focused on explaining how communities have adapted to climate change, with few studies evaluating the efficacy of region-specific adaptation approaches.

Since livelihood outcomes are significantly dependent on diverse and multi-dimensional variables, livelihood outcomes may vary from one household to the next and from one location to another. According to Aniah, Kaunza-nu-dem, and Ayembilla (2019), previous studies on climate adaptation have tried to identify universal coping patterns rather than differentiate between agro-ecological zones, villages, and types of households. Understanding these diverse patterns will assist in implementing effective climate change adaptation and mitigation strategies (Dhungana et al. 2017). Mpandeli et al. (2019) insist that while there are universal adaptation approaches, it is necessary to contextualize them to a local scale. However, the studies on livelihood adaptation in the face of climate change are still limited at the household level (Abid, Schneider, and Scheffran 2016).

Adaptation success can be defined in different ways; the local context defines what has to be adapted to, as well as who must adapt and whether measures at other scales are complimentary (Tompkins et al. 2018). However, quantifying adaptation efficiency is difficult due to our understanding of the incomplete and scattered nature of adaptation and the vast time spans it must be measured (Dilling et al. 2019). There is no agreement on what constitutes effective adaptation in practice (Owen 2020) because adaptation efforts are formed by a unique and regional combination of underlying elements like politics, money, motivation, power relations, and cultural values (Nsubuga et al. 2021).

According to Owen (2020), measuring climate change outcomes and implications is a critical but often neglected adaptation aspect. Different perspectives on what defines a risk and whether (or how) risk should be reduced may contribute to different perceptions of adaptation success (Dilling et al. 2019). What remains uncertain is the effectiveness and long-term sustainability of community-based adaption methods in the face of climatic variability and change. In this regard, there are few studies that sought to assess the effectiveness of adaptation methods used by communities in a mountainous setting, especially in the EFSR of South Africa. Hence, the primary objective of this study is to identify the most preferred adaptation strategies adapted by the local communities in the EFSR and the extent to which these strategies can be considered as effective in building resilient mountain communities. The findings of this research provide valuable information for evaluating the effectiveness of current climate change adaptation strategies implemented by local communities in the Thabo Mofutsanyane District. This study might be fundamental in designing mountain-specific adaptation plans that involve mountain communities in their design and implementation.

### **5.3.1 Sustainable Livelihood Framework**

A livelihood is a complex system comprising environmental, economic, social, and institutional components that drive the development of individuals' relationship with their geographical settings (Lan et al. 2021). The SLF proposed by the DfID continues to be an important and relevant approach for understanding livelihoods (Piggott-McKellar et al. 2019). The SLF has been widely used to assess livelihood sustainability (Pandey et al. 2017; Ming et al. 2019; Choden, Keenan, and Nitschke 2020; Islam, Islam, and Habib 2020; Ota et al. 2020). The SLF has gained universal recognition and provides a useful framework for assessing livelihoods at the local level (Ota et al. 2020). Call et al. (2019) point out that, though our knowledge on how climate impacts influence rural livelihoods is growing, previous studies

have been limited by an inability to consider both farm-based and off-farm livelihood strategies within the same context. As a result, the SLF approach is ideally adapted to research on natural resource management (on-farm activities) and off-farm activities within the same context, because it provides a simplified way of understanding and evaluating diverse livelihood systems (Ota et al. 2020). In this regard, this study adopted the SLF proposed by DfID to provide a detailed assessment of livelihood strategies that have been adopted by the households to alleviate climate change impacts.

The SLF consists of five key elements: the vulnerability context; capital assets; livelihood strategies; transforming structures and processes; and livelihood outcomes; and the relationships among all five elements. This paper focuses on the framework's three components: livelihood strategies, livelihood outcomes, and transforming structures and processes, while the framework's other components are beyond the scope of this article. *Livelihood strategies* include a variety and combination of community choices and activities to attain livelihood outcomes (Ota et al. 2020; Uddin et al. 2021). Livelihood strategies are classified as natural resource-based activities (collection or gathering products from woodlands and forests, crop cultivation, livestock farming, brick-making, weaving, and thatching) and non-natural resource-based activities (such as vehicle repair, rural manufacturing, and remittance) (Ellis 2000). In the context of this study, livelihood strategies help local communities transition from one type of strategy to another to achieve better outcomes in the face of climate change. According to Choden, Keenan, and Nitschke (2020), the SLF offers a platform for recognizing that livelihood strategies influence the potential for adaptation in households.

Policies and institutions, such as supporting structures (e.g., linked public and private organisations and their interactions) and procedures (e.g., applicable laws, rules, or operational arrangements), influence sustainable livelihood strategies and outcomes (Trang Thu and Loc 2021). *Livelihood outcomes* include the outputs or consequences of pursuing livelihood strategies (Connolly-Boutin and Smit 2016; Khayyati and Aazami 2016). The sustainable livelihood outcome indicators include the creation of working days, poverty reduction, well-being and capacities, livelihood adaptation and resilience, and natural resource base sustainability (Guo et al. 2022). Within the context of this study, the livelihood outcomes of interest determine whether or not the adaptation strategies implemented by households are effective. The possible *livelihood incomes*, therefore, include improved food security,

improved water availability, adoption of off-farm activities, improved social capital and sustainable use of livestock and crop-based livelihoods.

According to Guo et al. (2022), the DfID's sustainable livelihood analysis framework, has to be enhanced and expanded in response to changing research objectives. Previous studies on climate adaptation tried to identify universal coping patterns rather than differentiating between agroecological zones, villages, and types of households (Aniah, Kaunza-nu-dem, and Ayembilla 2019). However, it is recognised that there is no universal formula for effective adaptation and that all interventions need to be site-specific (Ensor et al. 2019). Mpandeli et al. (2019) insist that while broad adaptation strategies exist, they must be contextualised locally. The SLF allows for such contextualization, thus allowing the investigation of adaptation methods even at the household level. Unlike previous studies that limited their scope to SLF's five livelihood assets, this study includes geographical advantage and settlement types, which may influence how households adapt to environmental conditions induced by climate change. Even though several studies have used the SLF to assess poverty, only a few studies have been based on quantitative approaches (Donohue and Biggs 2015). Aazami and Shanazi (2020) state that the SLF is best applied when working with both quantitative and qualitative methods, hence the adoption of the mixed-methods that was used in this study.

## **5.4 Methodology**

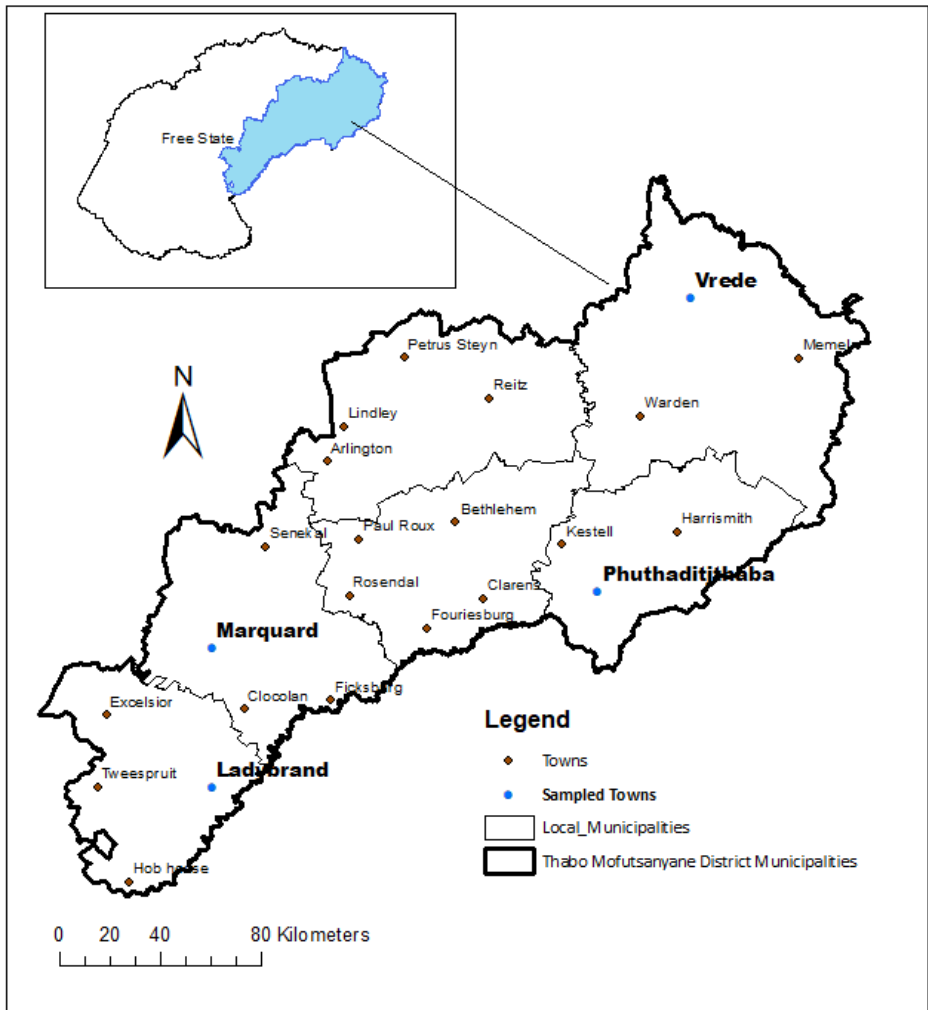
### *5.4.1 Study Area*

This study took place in the Thabo Mofutsanyane District in the EFSR of South Africa. The district covers six local municipalities: Setsoto, Dihlabeng, Nketoana, Maluti-a-Phofung, Phumelela and Mantsopa (Figure 5.1). The EFSR is bound by the Drakensberg and Maluti Mountains, Lesotho, KwaZulu Natal and Eastern Cape provinces. The district makes up almost a third of the Free State Province's geographical area, with an area of 33 269km<sup>2</sup>.

The EFSR is one of the highest producing agriculture regions in South Africa (Moeletsi and Walker 2012; Dube et al. 2019). The rural areas of TMD consist of commercial farming and small-scale farms, with major natural conservation centres such as the Platberg, QwaQwa National Park, the Maluti Mountain Range, and Sterkfontein Dam. The farming systems include commercial farming, small-scale farming, subsistence agriculture, pastoralism, and trade in medicinal herbs. These are the major natural resource-based livelihood options for the local people. Although agriculture is the principal occupation in the Maluti-a-Phofung

Municipality, non-agricultural income has become the primary means of support for many households (Myeni et al. 2019). In this district, rural settlements are mostly found at the periphery of the small towns, whereby the small towns are linked with the surrounding agricultural areas and villages that fall in their hinterlands. The EFSR was chosen for this study because of its geographical complexity which is characterized by drastic altitudinal variations and diversity of settlement types. In recent years the region has experienced serious climate change impacts associated with fluctuating rainfall patterns, frequent heavy rain storms, increased maximum temperatures, as well as occurrence of severe drought events (Botai et al. 2016; Mbiriri, Mukwada, and Manatsa 2019; Mohamed and Mukwada 2019; Abubakar, Scholes, and Newete 2020). As a result of the observed changing trends in climatic variables, some studies have pointed out that agricultural production, and socio-economic factors in the area were influenced by climate change (Nkonki-mandleni et al. 2018; Abubakar, Newete and Scholes, 2020; Melrose and Nel 2020; Mukwada et al. 2021). According to Melore and Nel (2020), smaller towns and villages are vulnerable to political, economic, and social risks exacerbated by climate change.

This study was undertaken in four local municipalities of the TMD, namely Maluti-a-Phofung, Phumelela, Mantsopa and Setsoto. The selection was based on altitude and population size. Thabo Mofutsanyane has the highest rural population (59.8 %) in the Free State Province, which is one of the reasons it was selected for this study. The four local municipalities within each elevation zone were chosen based on population size. The local municipalities that had the largest population and smallest populations from each elevation zone were selected for inclusion in the study. Thus, a total of four municipalities were included in the study sample. The selected municipalities under high elevation were Maluti-a-Phofung- (high population) and Phumelela- (low population) and under low elevation, Setsoto- (high population) and Mantsopa-(low population) were selected. In each selected municipality, a town settlement was randomly selected using random sampling python script in ArcMap 10.7.1.



**Figure 5.1** Location of the study area.

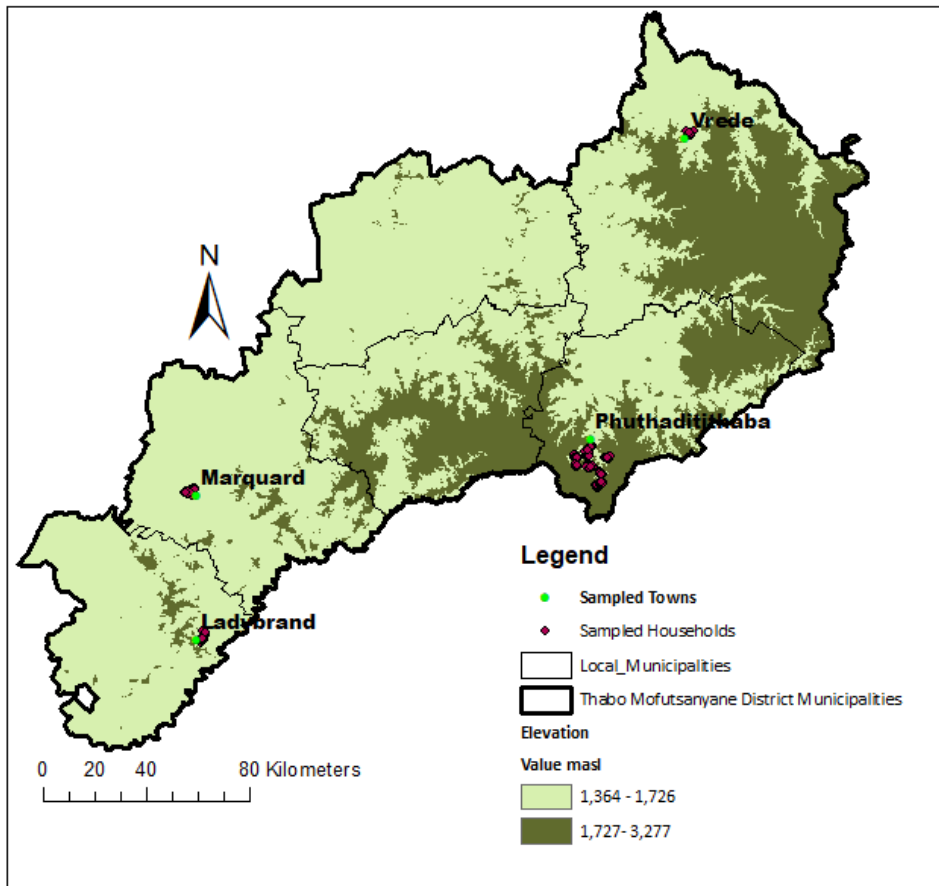
In the EFSR, rainfall, temperature, and natural disasters vary according to altitude. According to Mbiriri, Mukwada, and Manatsa (2018), the EFSR is one place that exhibits complicated terrain; as a result it provides a good example for comparing between flat terrain and highlands when studying climatic events such as droughts. The drastic variations in altitude provided a wide scope, and an opportunity for examining the differences in livelihood activities of local communities, climate change perceptions, and household perception on climate change adaptation in different elevation zones.

***The Environmental conditions in the Eastern Free State Region***

*Elevation*

The topography of the EFSR is mountainous, with altitudes ranging approximately between 1500 and 3000 metres above sea level (masl) at the peak of Maluti-Drakensburg Mountain

(Moeletsi and Walker 2012). Figure 5.2 below illustrates how the elevation of the current study area varies from 1364-1726 masl (lowest elevation) to the highest elevation (1727-3277 masl).



**Figure 5.2** Relief of the EFSR and Sampled Towns showing the Sampled households.

### *Climate characteristics*

The Free State Province is semi-arid except for the eastern and north-eastern parts, where humid subtropical climatic conditions are experienced (Moeletsi, Walker, and Adolf 2011). According to Moeletsi and Walker (2013), the east part of the region receives rainfall ranging between 500 and 600 mm, while the southern and western parts of the province receive lower than 400 mm precipitation. As the province's eastern section receives much more rainfall than the other parts of the area (Mbiriri, Mukwada, and Manatsa 2018), the region is more suitable for rainfed crop production than the rest of the province (Moeletsi and Walker 2013). The mean maximum temperatures range between 20°C and 22°C, and the minimum temperatures range between 5°C and -1°C (Dube et al. 2019). Due to variability of topography and geographical aspect within the region, the risk of frost attack varies significantly, with the early onset of frost

and late cessation of frost risk occurring over the east and south-eastern portions of the region (Moeletsi, Tongwane, and Tsubo 2016).

### ***Research design***

In this study, both quantitative and qualitative research methods were used. The SLF proposed by the (DfID 1999) was used to frame the research study. Aazami and Shanazi (2020) state that the SLF is best applied when working with qualitative and quantitative methods. The mixed-method approach allowed for the triangulation of results and provided numerous sources of data to create an extensive interaction between rural livelihoods and changes in environmental, socio-economic, development, and policy over time. In this mixed methods approach, three methods were employed to gather the data: questionnaire surveys, interviews, (Mkonda and He 2018) and thematic analysis of key informant interviews. According to Thurmond (2001), applying qualitative and quantitative methods verifies multiple data sources to increase confidence in the study's validity.

#### ***5.4.2 Data Collection***

Data were gathered through a semi-structured questionnaire survey (Appendix 4) and interviews. Part of the questionnaire had open-ended questions to allow the participants to explain further on their responses. The heads of the households were interviewed and whenever the head of household was absent, the next eldest household member was interviewed. The survey questionnaire, which was administered electronically on a handheld device after three days of training and pretesting, captured information on household characteristics such as household demography, assets, economic activities, access to agricultural services, and GPS record. A questionnaire survey was conducted to obtain information about the households' perceptions of climate variability and change impacts on their livelihoods, along with adaptation strategies introduced by the local communities. The design of the questionnaire was guided by the purpose of the study, which is to investigate the effects of climate change and variability on the livelihoods of mountain communities; and to identify the most preferred adaptation strategies adopted by the local communities and the extent to which these responses could be considered as effective in building resilient mountain communities in the EFSR. To analyse the climate change adaptation measures that were implemented by the household members in areas of various altitude and settlement type, the respondents were asked about how the present or past adaptation strategies worked for them (or were effective) and state the reasons. Also, if the respondents thought that the previous or current adaptation measures were not effective, they listed their reasons. To ensure the dependability of the survey, the following

steps were carried out: Firstly, the questions were constructed in a way that would reduce the likelihood that respondents would show biases. Secondly, in order to ensure that the questions were valid, the survey was also done in the local language for easier understanding. Lastly, local perceptions as interpreted through household questionnaires were put into comparison with the findings from the key participant surveys in an attempt to verify the results.

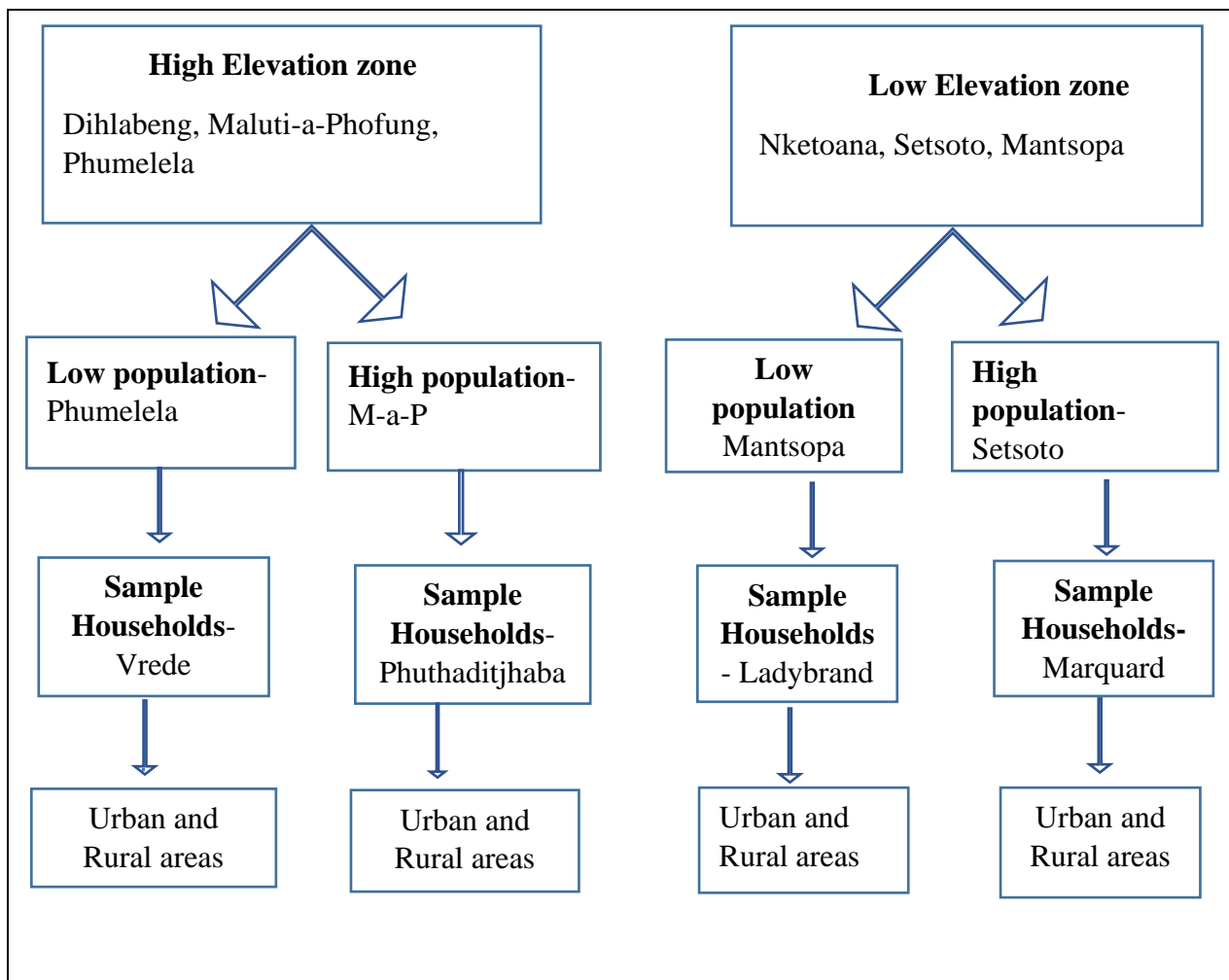
The formal interviews were held with two veterinary officers, one (V1) representing Phuthadjithaba and Vrede and another (V2) from Ladybrand and Marquard. The interviews held with the veterinary officers sought knowledge regarding climate change impacts on livestock farming, coping measures that the local communities implemented to reduce climate-related impacts on livestock, and collecting factors that might influence the adoption of climate change adaptation strategies among livestock-based households. Another two formal interviews were held with the Disaster Management Officer from M-a-P Local Municipality and the Environmental Management Officer at Thabo Mofutsanyane District. The key informant surveys were conducted to gather information about climate variability or change incidences, existing environmental management plans, disaster management plans, and environmental protection activities/natural resources management intended to prevent issues brought on by climatic change and fluctuations. Information from interviews held with key informants was used to validate the data that were gathered through the questionnaire survey. Interviews held with local government officials and surveys from the local communities enabled the triangulation of the research findings.

Before questionnaires were administered, a pilot test was done in one of the local villages in the Maluti-a-Phofung Local Municipality to test and validate the questionnaire to the respondents. The pilot test helped to adjust and refine the questionnaires for further precision and accuracy of the information. The results from the pilot questionnaire survey showed the probability of obtaining the same results when the same variables are repeatedly measured or when more than one person measures the same variable.

### ***Sampling design***

A multi-stage sampling technique was used for the sample selection. In the first stage, the study area was divided into two altitudinal zones based on elevation. The natural breaks classification method using ArcMap 10.7 was used to classify the local municipalities according to elevation. Based on Figure 5.2, high elevation was referred to as an elevation between 1669-3277 masl, and low elevation was defined as less than 1364-1668 masl. Based on this classification of the

study area into two elevation zones, Maluti-a-Phofung, Phumelela and Dihlabeng fell under the high elevation zone (1669-3277 masl), whereas Setsoto, Mantsopa, and Nketoana were in the low elevation zone (1364-1668 masl) (Figure 5.2). According to the Community Survey that was conducted in 2016, Maluti-a-Phofung had a population size of 353 433, followed by Dihlabeng 140 044, Setsoto 117 361, Nketoana 64 894, Mantsopa 53 525 and Phumelela 50 054 (<https://wazimap.co.za/profiles/district-DC19-thabo-mofutsanyane/>). Maluti-a-Phofung was the most populated local municipality accounting for 45% of Thabo Mofutsanyane's total population size, followed by Dihlabeng (18%), Setsoto (15%), Nketoana at (8%), Mantsopa and Phumelela at 7% (<https://www.cogta.gov.za/ddm/wp-content/uploads/2020/11/Thabo-Mofutsanyane-DM->). In the second stage, the six local municipalities were ranked according to population size. The local municipalities with the largest and smallest populations were selected for inclusion in each altitudinal zone, resulting in four municipalities in the study sample. Under high elevation, the selected municipalities were Maluti-a-Phofung-(high population) and Phumelela-(low population). In the low elevation, Setsoto and Mantsopa were selected to represent high and low population municipalities, respectively. Stratified sampling was undertaken in each settlement to include urban and surrounding rural environments. In each sampled settlement, households were randomly selected. Only the households in which household heads were present during the survey were included in the study.



**Figure 5.3** Criteria for selecting sample households

### *Sampling size*

A proportional sampling method was applied to calculate the sample size. The sample size for the questionnaire survey was calculated based on the ratio of the number of households in the local municipality. Four hundred respondents were included in the survey (Table 5.1). In this study, we calculated the statistically admissible minimum household sample size at a 95% confidence level with a 5% level of precision using Yamane's (1973) formula ( $n = N / 1 + N(e)^2$ ), where  $n$  denotes the sample size,  $N$  indicates the population size. The sample sizes per municipality are presented (Table 5.1)

**Table 5.1** Sample size

	HIGH ELEVATION ZONE		LOW ELEVATION ZONE	
<b>Local Municipalities</b>	<b>Maluti-a-Phofung</b>	<b>Phumelela</b> (Low population)	<b>Setsoto</b> (High population)	<b>Mantsopa</b> (Low population)

	(High population)			
<b>Population size</b>	353 453	50 054	117 361	53 525
<b>Number of Households</b>	110 725	14 586	37 246	16 951
<b>Minimum sample size by proportionate sampling</b>	(110 725/179 508) x 400	14586/179 508) x 400	(37 246/ 179 508) x 400	(16951/179 508) x 400
<b>Actual Sample size</b>	247	33	82	38
<b>Total</b>				400

#### 5.4.3 Data analysis

The analysis was done in Microsoft Excel 2016 and SPSS (Version 17.0) statistical software. This study utilized descriptive statistics (frequencies and percentages), crosstabulation and t-test by coding the responses of surveyed households to various questions. Before the Student T-Test was conducted, data were tested for normality using the Kolmogorov-Smirnov test to determine if the data required parametric or non-parametric tests. The estimation of the t-test was justified by the normal distribution of the sample. The sample groups (settlement type and elevation) were in two pairs; hence, the use of t-test to determine the significant difference between the groups' values was appropriate. The Student T-Test was employed to check if there might be any statistically significant differences between climate change adaptation strategies implemented by the local communities in different settlement types and elevation zones. The data gathered from the interviews was organized into themes using thematic analyses. Qualitative data were coded through indexing of data and categorized into different emerging themes. Thematic analysis was done on gathered data based on the transcripts of interviews and questionnaire surveys. The qualitative data from the key informants were narrated and interpreted. Data from the analysis were presented in graphical and tabular formats.

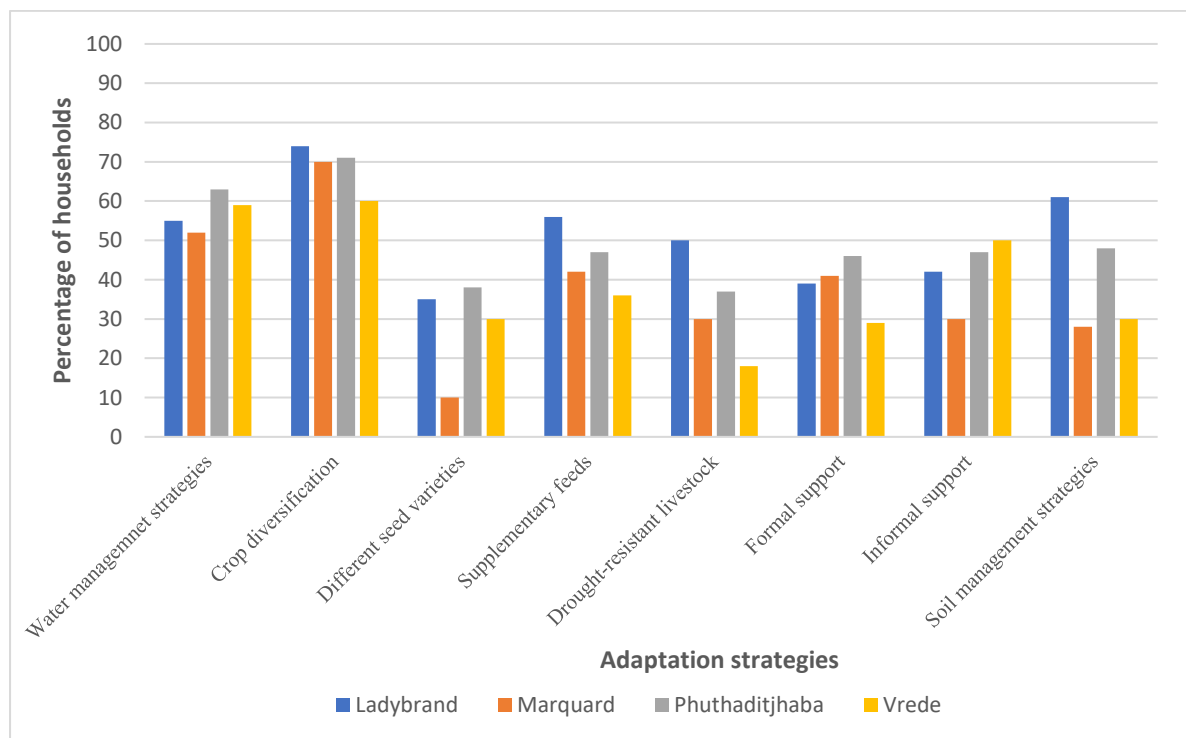
### 5.5 Results and Discussion

The following section discusses the adaptation measures implemented by the respondents across the sampled towns, according to elevation zone and settlement type, to alleviate climate change effects on their livelihoods. As noted earlier, the study objective was to identify the most preferred adaptation strategies adopted by the local communities in Thabo Mofutsanyane

District Municipality of South Africa, and the extent to which these strategies could be considered effective in building resilient mountain communities. In the Thabo Mofutsanyane District Municipality, local communities have been impacted by climate change in many ways to which they have adapted in order to enhance their resilience. These strategies are discussed below.

### 5.5.1 Adaptation strategies in response to climate change

Figure 5.4 shows the percentages of adaptation measures implemented by the local communities in the sampled towns within the TMD. Results from the household survey indicate that the main adaptation measures implemented by the local communities in the four sampled towns include water management strategies, crop diversification, sourcing of supplementary livestock feeds and soliciting formal support from local government and informal support from relatives and neighbours.



**Figure 5.4** Adaptation measures across the sampled towns

#### *Water management strategies*

According to the survey results, rural communities in the TMD have high regard for water and soil management practices that they have designed to cope with climate change and variability. Water management strategies were reported as a crucial aspect of climate change adaptation

by over fifty percent of the respondents across the sampled sites, with respondents from Ladybrand 21 (55%), Marquard 42 (52%), Phuthaditjhaba 155 (59%), and Vrede 20 (63%). The significant proportion of the local households who implemented water conservation strategies could have been influenced by previous experiences of climatic stresses on water quantity and quality. Most local communities have modified their behavior and environment as a way of coping with water shortages that have been exacerbated by climate change and variability in current years. The respondents from the sampled towns reported that they bought water tanks to store water, as well as buy water. However, the respondents from Phuthaditjhaba reported that they harvest rainwater and collect water from the water tanks that are delivered by the local municipality. They also reported that they walk long distances to collect clean water from relatives and friends from Qwaqwa villages, Phuthaditjhaba. These results are consistent with previous studies that have mentioned water conservation methods such as harvesting rain water using buckets and storage tanks (Mahdu and Mills 2019; Talanow et al. 2021).

#### *Soil management strategies*

Due to climate change, the respondents carried out soil management strategies to improve soil fertility and soil moisture availability. According to Brevik (2013) and Goa and Zewude (2021), heavy rainfall may cause loss of soil nutrients. They also noted that an increase in maximum temperatures may increase soil temperatures and soil moisture deficit, thus depriving the ability of crop plants to use soil nutrients for maximum growth. Figure 5.4 shows that households from Ladybrand 19 (61%), Marquard 11 (28%), Vrede 3 (30%), and Phuthaditjhaba 77 (48%) use different inorganic and organic fertilizers to enhance soil fertility. The respondents highlighted the use of livestock manure from chickens, sheep, goats, and cows to enrich the soil in their fields. Some respondents said that they used crop residues, grass, and tree leaves to improve soil fertility. For example, one of the respondents from Phuthaditjhaba reported pruning the vegetable leaves and allowing them to decompose to improve soil fertility. This suggests that the local communities in the study area have perceived and realized the adverse impacts shifts in temperature and rainfall have on soil moisture, fertility, and crop production, and have therefore, taken measures to reduce such impacts. These soil management strategies show how communities in the surrounding area can successfully use accessible resources to enhance soil fertility. Similar examples can be drawn from the Yatta sub-county in Kenya and the Aguire District of Niger, where communities were reported to be using organic manure to enhance crop yields and soil fertility (Ado et al. 2019; Agesa et al. 2019).

Despite the dependence of local communities on indigenous knowledge systems to cope with climate change, use of organic manure, which has been widely adopted, has no uniformity in its application across the sampled towns. The findings of the research (Figure 5.4) show that only a small percentage of respondents from Vrede (30%) and Marquard (28%) implemented soil management strategies. The low capacity of the local respondents to adapt to changes in soil infertility in Marquard is likely going to be surpassed by increasing weather-related risks such as floods or heavy rains and social impacts such as unavailability of labour, lack of information on how to apply fertilizer and health-related reasons, which seem to be affecting communities in the lower elevation zone compared to the higher elevation zone. Some respondents reported that due to unaffordability of inorganic fertilizers, application of mulching and composting could reduce costs of improving soil fertility. The reduction or elimination of the use of inorganic fertilizers due to soaring costs, increased soil erosion due to heavy rains, and water shortages arising from recurrence of severe droughts have forced communities to rely on mulching and organic manure. Avane et al. (2021) state that organic fertilizers cover and shade the soil from extreme sunlight and help the soil to retain soil moisture and keep it cooler than using inorganic fertilizers.

#### *Crop management strategies*

In dealing with climate change effects on livestock and crop production, namely crop loss, reduced crop yields, reduced livestock fodder, livestock diseases and livestock mortality, the respondents have established locally based crop and livestock-related adaptations to maintain their livelihoods. Crop diversification, in which households grow more than one crop type to adjust to climate fluctuations, is practiced by a considerable proportion of respondents. Crop diversification is practiced by 74 percent, 70 percent, 60 percent, and 71 percent of households in Ladybrand, Marquard, Vrede, and Phuthaditjhaba (Figure 5.4). Some of the respondents who had diversified did so because the new crops they adopted could withstand droughts and low temperatures, while also providing livelihood options to many households to stabilize their food supplies and income.

Among the number of households who practice crop farming across the study area, respondents reported using drought or frost-resistant seed varieties to alleviate the impacts of frost, drought, and unpredictable rainfall. The use of different crop varieties offers two advantages: firstly, it increases crop production, and secondly, it helps to identify crops that are better suited to the new climatic conditions (Karki et al. 2019). A few households (Figure

5.4) in Marquard 4 (10%) preferred growing drought or frost-resistant crops compared to the respondents from other sampled towns, who reported a more significant percentage (Ladybrand 11 (35%), Vrede 3 (30%) and Phuthaditjhaba 62 (38%). For example, some respondents reported that they also plant crops such as spinach, cabbage, and onions in winter, and some crops that do not require much water, namely, soybeans, pumpkins, maize, and spinach. More than fifty percent of the households that were interviewed, grew spinach. The respondents said spinach could adapt well to any change in the climate; hence they plant it more than other crops. Adjusting farming practises to grow drought-resistant crops has been recommended as one strategy for adjusting to low rainfall and drought hazards (Adzawla et al. 2019; Agesa et al. 2019; Kom et al. 2020). Limited adoption of measures such as growing drought/frost-resistant crops, for example, in Marquard might be due to a lack of knowledge or resources to implement advanced measures at a household level.

#### *Livestock management strategies*

Local households reported several techniques for coping with the uncertainties and hazards of climate change and variability in livestock farming, including sourcing of supplementary feeds, livestock vaccination, and usage of drought-resistant livestock. The respondents purchase supplementary feeds as a way of dealing with low livestock feed availability caused by persistent drought, and the delayed onset of rains. Fewer respondents from Vrede 2 (18 %) who practiced livestock farming introduced drought-resistant livestock compared to Ladybrand 9 (50%), Marquard 14 (30%) and Phuthaditjhaba 31 (37%). In addition to purchasing livestock feeds, households from the sampled towns supplement their livestock feeds with maize stalks, grass, and planted fodder. The respondents from Phuthadjithaba and Ladybrand harvest hay and keep it for winter. Two respondents from Ladybrand planted winter fodder during the latter part of the rainy season in March and did not harvest it but allowed their livestock to graze on the green fodder in the backyard garden. Some respondents admitted to allowing their livestock to graze on vegetables that did not thrive well in their backyard gardens. One livestock-based respondent in Vrede stated that he used to grow fodder for his herd, but their plants were damaged by rat infestation.

Although Phuong et al. (2018) recommend livestock vaccination as the alternative to deal with livestock diseases like Rift Valley fever, foot and mouth diseases and foot rot induced by climate change, only a small number of respondents 11 (2.75%) had vaccinated their livestock. Studies have reported that one of the manifestations of climate change is the increased

incidence of livestock diseases (Aryal et al. 2021; Mihiretu, Ndemo, and Tesfaye 2021). Batisani et al. (2021) state that adjusting the livestock vaccination calendar is relevant and crucial to controlling diseases since seasons have shifted, necessitating timely vaccination. The small number of respondents who have vaccinated their livestock was due to lack of training, financial constraints, and limited access to such information on the importance of livestock vaccination, according to the local veterinary officer (V1) from Phuthaditjhaba, few individuals who raise livestock vaccinate their diseased livestock because of financial constraints and other socio-cultural factors. V1 further explained that a household with 40 sheep might not sell one sheep to get money to treat the rest of the 39 sheep due to cultural and social reasons such as lack of information, food insecurity and preferred use of traditional medicines. Some respondents from Ladybrand and Qwaqwa reported using forest resources such as roots and leaves to treat animal diseases. However, one of Ladybrand's livestock-based households claimed that medicinal plants were not always effective for treating livestock, necessitating the purchase of vaccines. V2 stated that through the meetings conducted by the agricultural extension officers they ensure that the local communities are aware of the livestock diseases and what control measures to take. The veterinary officer from Ladybrand and Marquard advised the local communities to vaccinate their livestock, and some livestock-based households come to have their livestock vaccinated. However, most livestock farmers might choose not to vaccinate their livestock. Their priorities may be different because, instead of selling some of their healthy livestock to generate income to treat their sick livestock, they prefer to cover household needs rather than livestock health. Also, the other reason highlighted by the veterinary officer from Ladybrand and Marquard for people not selling their livestock might be that livestock-based households keep their livestock in order to uphold their social status.

Similarly, several chicken keepers had coping strategies. Several keepers said they provided shelter to their chickens to protect them from hail. They also protected them from cold weather by lighting gas or paraffin heaters or firewood stoves which they placed inside the chicken coops to keep the chickens warm during winter. Some respondents responded to climate change by providing semi- shade shelters that were highly ventilated and enclosed in order to reduce chicken mortality caused by lower temperatures and hail. *"I have built a poultry coop because some of my chickens were killed by hail,"* one Qwaqwa villager remarked. One respondent from Vrede reported using sacks and placing grass on the ground during severe rains to give shelter and protect livestock such as goats, cattle, and lambs from becoming sick due to damp ground.

Some respondents from Ladybrand, Marquard, and Qwaqwa villages indicated they had to employ workers to look after their livestock due to a lack of space and additional labour because of water shortages. The livestock system was different across the region. For example, in Qwaqwa, the local livestock-based communities practiced transhumance, involving the movement of livestock into the mountains. Local communities in Ladybrand, Marquard, and parts of Vrede grazed their cattle on rented areas on commercial farms or erected kraals on the outside of the township and hired herders to look after their livestock. However, socio-economic issues such as land scarcity, money, and thievery influenced the number of animals owned. V2 from Marquard and Ladybrand stated that there was a lack of grazing land for the local communities because there were more livestock than what the existing land can sustain.

#### *Socio-economic strategies to mitigate climate change*

Local communities have developed socio-economic coping mechanisms to decrease the impact of climate change and variability. A small number of the respondents 11 (2.75%) reported altering their food intake or changing their diet to safeguard food security due to climate change. Also, a few respondents 10 (2.5%) from the towns included in the study migrated as a coping strategy related to climate change.

Income source diversification was one of the ways through which respondents responded to the impacts of climate change. The results show that 18 (47%) of the respondents from Ladybrand, 20 (24%) from Marquard, 10 (30%) from Vrede, and 59 (24%) from Phuthadjithaba were self-employed. Self-employment-based activities were linked to petty trading, such as leasing land, selling non-agricultural produce, lending money, selling labour, as well as catering at social events, operating driving schools, and construction related activities. Some households diversified their on-farm revenue sources by selling livestock, crop products such as crushed maize, fodder, forest products such as fuelwood, thatching grass, timber poles, and leasing out portions of their farms. However, due to climate change, the increased demand for natural resources (pastures and firewood) has also contributed to overgrazing and poor land management, resulting in land degradation. The respondents from Qwaqwa villages sell crops and vegetables during the rainy season. Some respondents from Qwaqwa reported selling dried vegetables and crops such as beans, peas, pumpkin, and chicken feed made from crushed maize during winter. However, it is important to note that practice of selling dry harvested and stored crops may become ineffective or an unstable source of income during periods of disease and pest outbreaks. Seventeen respondents reported selling livestock

and livestock products to generate income for food purchases, to repair damaged houses, or to recover from agricultural losses. One of the respondents from Ladybrand said, “*I sell sheep to cover for food shortages.*” Another male respondent from Ladybrand said he sheared sheep and to sell the wool every August. A respondent from Qwaqwa villages said, “*We are not selling livestock because it is a profitable business, but because we want to cover expenses at home.*” Another respondent from Qwaqwa said, “*I sell piglets and meat to reduce stress about their food, water and space.*” Similar cases were reported in Mzimba, Lilongwe and Nsanje Districts, Malawi and Mopani District Municipality, where the local communities sold their livestock to compensate for lower income arising from low crop yields during low rainfall and drought events (Kaumbata et al. 2020; Nembilwi et al. 2021).

#### *Informal support from friends and relatives*

Respondents from Ladybrand 16 (42%), Marquard 24 (30%), Verde 17 (50%) and Phuthaditjhaba 117 (47%) indicated that informal support from relatives and friends was one of the ways of adapting to climate change. Such support involved the provision of temporary jobs, dividing income and labour, borrowing money from family and neighbours, receiving help through provision of food, water, livestock feeds, livestock manure, and rendering labour to affected families. The respondents acknowledged that having access to resources lessened climate change impact on their livelihoods. Collaborative development practices and financial incentives also played a substantial role in improving social relationships within households. For instance, establishing a vegetable nursery at schools, where the local communities planted and sold vegetables, was reported in Ladybrand, Marquard and Phuthaditjhaba. Livestock cooperatives were reported to exist in Ladybrand, Marquard, and Vrede. According to respondents whose livelihood depended on livestock holding, livestock cooperatives assisted their households with space to keep and look after one another’s livestock, which was beneficial, especially to respondents who were employed elsewhere during the day. Most of the respondents accredited the enhancement of social relations in the local communities. Similar findings from Wolaita Zone in Ethiopia and Jhalokathi, Bagerhat, and Satkhira districts in southwestern Bangladesh, have been reported (Bedeke et al. 2019; Aryal et al. 2020). Unfortunately, social networks can unfortunately be unsuccessful, especially in times of extreme weather such as cyclones, floods, and droughts, where most local households are simultaneously affected and unable to help each other (Son and Kingsbury 2020).

#### *Formal support*

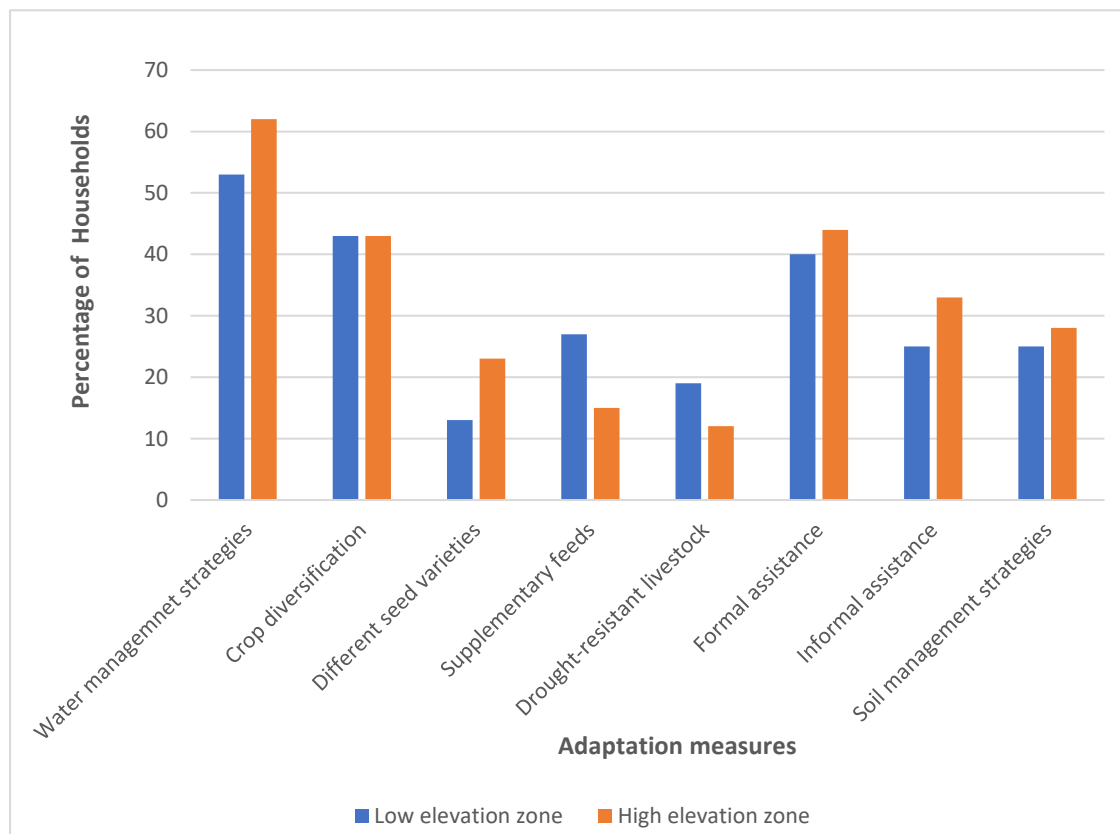
Fifteen (39%) respondents interviewed from Ladybrand, compared to 48 (59%) from Marquard, 21 (64%) from Vrede and 112 (45%) from Phuthaditjhaba were receiving monetary grants from the government. In all cases, the main support received from the government included grants (child or disability grants) and old age pensions. Some of the respondents who received the grants stated that the grants assisted significantly in meeting household requirements, especially during winter when they could not grow or sell vegetables due to water shortages and decreased minimum temperatures. Such respondents stated that in times past they used to produce crops in winter since water from taps and adjacent rivers was accessible for their households. They sprinkled water on their crops to protect them from frost. The benefits of social grants have been widely reported in some parts of South Africa, for instance in Tshivhulani Village, Limpopo and Mtubatuba Local Municipality in KwaZulu Natal, where social grants have assisted local communities to increase their resilience to cope with climate change (Masunungure and Shackleton 2018; Sibiyi 2019).

Local communities are also receiving formal support from the government through water supply in areas that face critical water shortages. Most of the respondents stated that they collect water from the delivery vehicles supplied by the local municipality. One respondent from Vrede stated that water could no longer be obtained from the Emanzini Dam, which dried up in 2016. Since then, the local municipality has been delivering water to residents. However, according to a study that was conducted in seven villages of Qwaqwa, most of the local communities were affected by poor service delivery, with the quality of water supply falling short of norms and criteria established by legislation (Manyama 2020). In the same vein, the National Department of the Environment officer stated that rural households in Qwaqwa villages do not have access to formal municipal services such as access to reliable, clean water and waste management. Other means of support from the government reported by a few households in Ladybrand include government supply of livestock feeds to livestock holders. However, most of the respondents that practiced livestock farming reported that they used to receive help from the government, but that has not occurred in the past ten years. They stated that they had been on waiting lists to receive funds, but they had not been contacted. The veterinary officer from Ladybrand and Marquard reported that though help from the government was available, it was not enough, and resources were often late. Hence, the contribution from the government was rendered ineffective. The Disaster management office and the National Department of Environment office stated that it had been more than six years

since the Change Climate Response plan was developed, but it has not yet been implemented or tested.

5.5.2 Perceived climate change adaptation strategies according to elevation zone.

Figure 5.5 presents the results of climate change adaptation strategies adopted by the respondents in the high elevation zone (Phuthaditjhaba and Vrede) and low elevation zone (Ladybrand and Marquard).



**Figure 5.5** Perceived climate change adaptation strategies in the low and high elevation zones.

The questionnaire survey administered across the two elevation zones revealed some similarities and differences in the adaptation measures taken by local household members. Adaptation strategies such as water management tactics, crop diversification, soil management, and formal support were frequently reported across the two elevation zones (Figure 5.5). The study hypothesized that there is a difference between the adaptation measures implemented by the local communities from the low elevation and those from high elevation zones. According to results from the t-test that was undertaken (Table 5.2), there was no significant variation between the adaptation measures, namely water management tactics, crop diversification, soil management strategies, and formal support received by the respondents from the two elevation

zones ( $p>0.05$ ). This might indicate that respondents from the two-elevation zones had similar experiences with water scarcity and reduced soil fertility due to climate change.

**Table 5.2** Standard deviation, mean, and t-test scores of respondents on climate change adaptation strategies in low and high elevation zone in the EFSR.

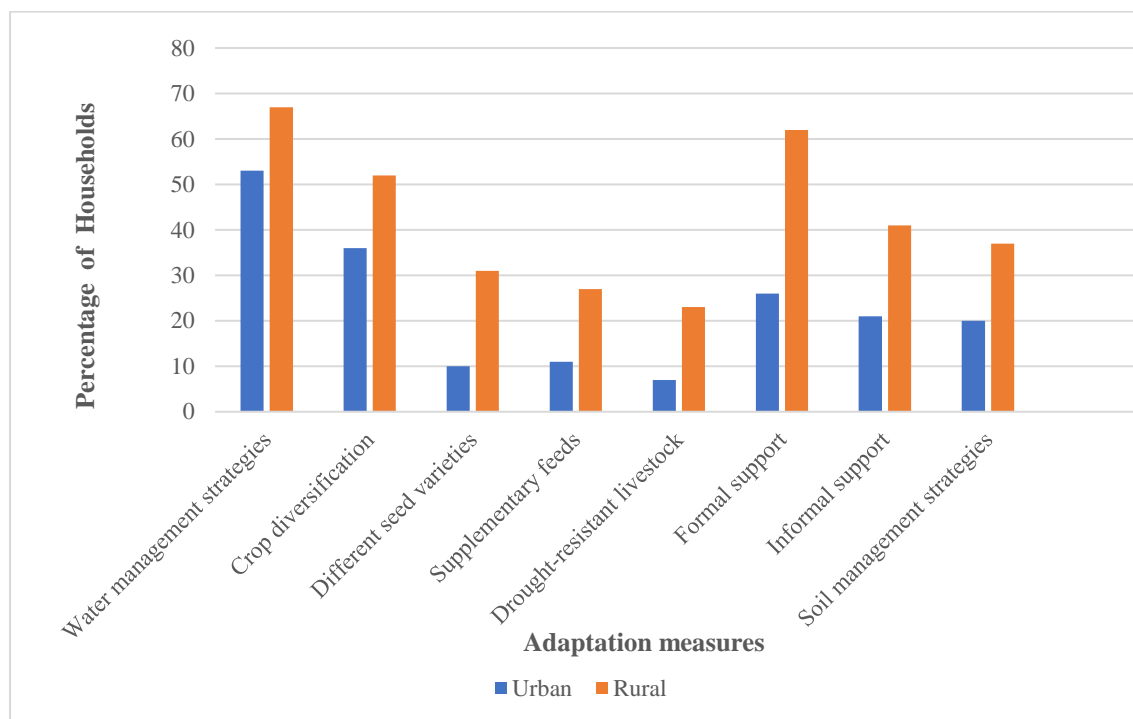
	Sig.	t	Sig. (2- tailed)	Mean Difference	Std. Error Difference
Crop diversification	0.940	-0.037	0.970	-0.002	0.054
Water management strategies	0.011	-1.741	0.082	-0.093	0.054
Soil management strategies	0.171	-0.666	0.506	-0.033	0.048
Formal support	0.174	-0.634	0.527	-0.034	0.054
Informal support	0	-2.611	0.009	-0.141	0.054
Supplementary feeds	0	2.733	0.007	0.116	0.42
Different seed varieties	0	-2.418	0.016	-0.105	0.044
Drought resistant breeds	0	2.003	0.046	0.076	0.038
Petty trade	0.009	1.317	0.189	0.034	0.026

However, there were differences regarding some adaptation strategies implemented by the respondents from the high elevation zone and those from the low elevation zone. The Student T-test results indicated a significant difference between the adaptation measures, namely using frost/drought-resistant seed varieties, informal support from friends and relatives, purchasing supplementary feeds, and using drought-resistant livestock employed by the respondents from the two elevation zones ( $p<0.05$ ). This shows that the respondents' perceptions regarding the implementation of adaptation strategies varied between respondents in low and high elevation zone. This might indicate that respondents from the two-elevation zones had different experiences in terms of reduced crop yields, reduced livestock health and availability of livestock feeds, as well as their social networks and connections with relatives and friends. Twenty-three percent of the respondents from the high elevation zone (Vrede and Phuthaditjhaba) reported using frost/drought-resistant seed varieties. Also, a slightly higher percentage of respondents 93 (33%) in the high elevation zone received support from relatives and friends than the respondents 30 (25%) in the low elevation zone. In Phuthaditjhaba, most of the respondents reported that they collected water from relatives residing in other Qwaqwa villages due to low water quantity and quality. On the other hand, the use of supplementary

feeds 32 (27%) and drought-resistant livestock 23 (19%) were the most preferred strategies for climate change adaptation by the respondents in the low elevation zone (Ladybrand and Marquard) compared to the respondents in the high elevation zone. This is because, compared to the high elevation zone, local populations whose livelihoods rely on livestock farming from the low elevation zone may be more vulnerable to climate change impacts on livestock, such as decreasing livestock fodder and heat stress.

### 5.5.3 Perceived climate change adaptation strategies according to settlement type

The results of this study revealed differences in the implementation of adaptation measures implemented by urban and rural households. Figure 5.6 shows the percentages of perceptions adaptation strategies to climate change held by the respondents according to settlement type (urban and rural areas).



**Figure 5.6** Climate change adaptation strategies according to settlement type.

The study hypothesized that there is a difference between the adaptation measures implemented by the local communities in the urban and rural areas. The t-test results (Table 5.3) indicate that there is a significant difference between the adaptation measures adopted by urban and rural households ( $p < 0.05$ ). This shows that the perceptions of the respondents regarding the implementation of adaptation strategies such as purchasing livestock supplementary feeds, use of different seed varieties, drought-resistant livestock and soil management strategies varied between the respondents in urban and rural areas (Figure 5.6). For example, a higher percentage

of rural respondents than urban respondents used the following crop and livestock management strategies namely, the use of soil management practices 68 (37%), adopting drought-resistant livestock 42 (23%), use of different crop seed varieties 58 (31%), and purchasing supplementary feeds 51 (27%). The results also reveal that there is a significant difference between the mean responses of the urban and rural households on, as indicated by the t-test.

**Table 5.3** Mean, standard deviation, and t-test scores of respondents on climate change adaptation strategies in urban and rural areas in the EFSR.

	Sig.	T	Sig. (2- tailed)	Mean Difference	Std. Error Difference
Crop diversification	0	-0.328	0.001	-0.161	0.049
Water management strategies	0	-2.741	0.006	-0.134	0.049
Soil management strategies	0	-3.843	0	-0.169	0.044
Formal support	0	-7.686	0	-0.357	0.046
Informal support	0	-2.871	0.004	-0.142	0.049
Supplementary feeds	0	-4.727	0	-0.160	0.034
Different seed varieties	0	-5.386	0	-0.209	0.039
Drought resistant breeds	0	2.71	0.007	0.322	0.119
Petty trade	0.328	0.489	0.625	0.012	0.024

These differences might be because most rural communities' livelihood systems are dependent on scarce natural resources such as crop-livestock farming, pasture, forest products, fodder, and water, which are mainly vulnerable to climate change. As a result, the implementation of adaptation strategies to climate change implications in rural areas varies from that in urban areas. Also, the results show that the respondents from rural areas received formal 115 (62%) and informal 77 (41%) support from the local government and relatives/neighbours compared to respondents in urban areas (formal 56 (26%) and informal 46 (21%) support).

## **5.6 Perceived effectiveness of adaptation measures to climate change in the EFSR**

A significant number of respondents, 362 (90.5 %), reported implementing different adaptation techniques to climate change impacts. When the respondents were asked if the adaptation measures, they adopted had been working for them or not, 304 (84%) reported that the

adaptation measures worked for them effectively. In Ladybrand 32 (84%), Marquard 62 (77%), Vrede 22 (65%) and Phuthadjithaba 188 (76%), respondents reported that some of the adaptation measures were successful. A significant percentage of the respondents reported that some of the adaptation measures were effective as they saw expected results such as increased crop yield, improved soil fertility, reduced water problems, and improved livestock health from the different livelihood outcomes. Owen (2020) argues that the challenge for evaluating adaptation is that climate change operates on longer timescales than many other projects. However, the effectiveness of adaptation methods must be assessed based on their capacity to lessen the impacts of climate change and variability on local communities' livelihood activities. The adaptation measures implemented by some local communities might have been implemented based on the climatic change that the respondents had perceived in the past 5-10 years.

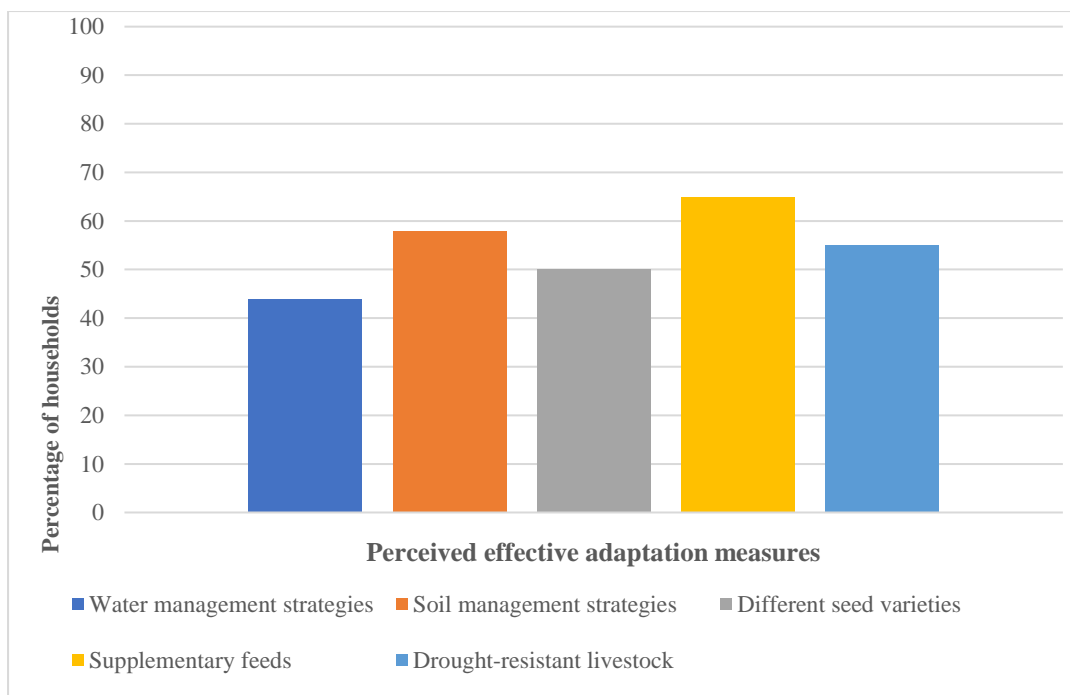
The results show that these adaptation strategies, to some extent, helped the local households alleviate the effects of climate change on natural-based resources, infrastructure, and socio-economic systems. However, the effectiveness of these measures varied amongst the local communities depending on the type of livelihood activities, climate implications they faced, and measures undertaken to alleviate these impacts. One of the reasons for differences in perceptions held by the households regarding the effectiveness of some of the adaptation measures might be that the impacts of climate change vary across the district and different aspects are also affected differently based on the type of livelihood activities. Some of these adaptation measures that were classified as effective have repeatedly been used by the respondents.

Among the adaptation strategies identified by the respondents, water and soil management strategies, use of different seed varieties, purchase of supplementary feeds and adoption of drought-resistant livestock were the most recommended strategies as indicated by the respondents. The findings corroborate those from a study, that was conducted in the highlands of Ethiopia by Alemayehu and Bewket, (2017), which revealed that soil, crop, and livestock management strategies, could effectively reduce the impacts of climate change and variability. However, such adaptation measures reduce current vulnerabilities without necessarily taking into account for future climate change (Antwi-Agyei et al. 2014). Table 5.4 and Figure 5.7 show the perceived percentages of the adaptation measures that were reported as effective by the respondents, showing the importance of crop-livestock-related livelihoods to the communities.

**Table 5.4** Percentage of respondents who perceived that the adaptation measures to climate change were effective

<b>Adaptation measures</b>	<b>Water management strategies</b>	<b>Soil management strategies</b>	<b>Different seed varieties</b>	<b>Supplementary feeds</b>	<b>Drought-resistant livestock</b>
<b>Number of respondents implemented</b>	238	110	80	75	56
<b>Percentages of effective measures</b>	105 (44%)	64 (58%)	40 (50%)	49 (65%)	31 (55%)

The analysis of the data from the questionnaire survey shows that most respondents regarded crop-livestock-based adaptation measures to climate change as effective. However, it is crucial to note that the majority of these farm-based adaptation measures become inefficient or unstable as a result of unforeseen climate hazards. In response to climate change adaptation effectiveness to livestock farming, the respondents reported improved livestock health through supplementary water and stock feeds. A combination of harvested grass (hay), crop residues, and supplementary feeds helped the communities whose livelihood depended on livestock holding to cover fodder shortages. Some respondents said mixing the feeds was reported to be less expensive than buying the already mixed portion of the livestock feeds. In addition to improving livestock health through supplementary water supply and supplementary stock feeds, introducing drought-resistant livestock also enhanced livestock health. However, according to Etana et al. (2023) livestock production from rearing dairy cows and on-farm income from the sale of milk products were among the strategies perceived to be successful by farmers in Kembibit, Kuyu, and Boset Districts, Ethiopia.



**Figure 5.5** Perceived percentages of effective adaptation measures to climate change

Most respondents stated that the recurrence of drought might have resulted in water shortages, and negatively impacted their livelihood activities. The respondents reported that they had been facing water shortages since 2015. Of the 238 (57 %) of households who reported adapting to reduced water quantity and quality, 105 (44%) acknowledged using different water management strategies as a coping strategy. These strategies included water storage and water conservation. Better management of water use has called for the improvement of the local communities' daily livelihoods and improved health because of proper water management strategies. Some respondents opted to buy storage facilities to store water, collect rainwater in containers and use grey water for crop irrigation and household duties that do not require potable water. Such measures have also enabled some respondents who do off-farm businesses to continue with their businesses. One self-employed respondent from Phuthadjithaba mentioned buying a storage tank to store water to wash their customers' hair. Another respondent said, *"I bought a storage tank for water in order to provide catering services for my business."* Furthermore, the respondents who bought water stated that they had been buying water for some time, considering their health first as more important than the expenses they face in continuously buying water. However, some respondents stated that buying water had become too expensive.

Based on observations of adaptation measures undertaken in the study area, such as implementation of soil management techniques and use of drought/frost resistant seed varieties,

the respondents evaluated if these strategies were effective and enhancing crop yields. The respondents reported soil management strategies such as mulching and application of organic and inorganic fertilizers as effective. Fifty-eight percent of the respondents maintained that the use of different organic fertilizers offered several advantages. Firstly, organic manure is accessible and affordable to most households, compared to the cost of buying the inorganic fertilizers. The majority of the strategies implemented by local households is greatly dependent on both their perceived affordability and effectiveness in combating climate change (Ado et al. 2020). The respondents noted that it was easy to access the manure from neighbours or from pasturelands. Secondly, due to high yields, some respondents stated that they sold surplus crops during the rainy season when they harvested more crops than required by their household. In fact, some respondents stated that the use of inorganic fertilizers did not work, while others bemoaned the cost of inorganic fertilizers. Similarly, in the Kembibit, Kuyu, and Baset districts of Ethiopia, the application of fertilizers improved soil water retention and moisture, thereby reducing crop loss, and increasing yields (Etana et al. 2023). However, the local communities in Khyber Pakhtunkhwa, north-west Pakistan, did not consider adaptive measures such as crop diversification and changing fertilizers as effective means of improving farm productivity (Ullah et al. 2019). This might be because the use of improved seeds requires a right amount of rainfall in order to improve yields and benefit local communities. (Etana et al. 2023). In Ghana, agro-processing and petty trade were perceived to be the most successful off-farm activities, contrary to our study's findings that indicated that on-farm techniques were seen as effective.

The formal support from the local municipality and informal support from friends and relatives indirectly contributed to the success of these adaptation measures. For instance, sharing income and labour among households, borrowing money from relatives or neighbours, and getting assistance such as shelter, food, and labour to affected families are some of the socio-related activities that enhance the effectiveness of the climate change adaptation measures. The success of the adaptation measures mentioned above was also enhanced by the government grants and the direct provisioning of resources such as water. The supply of water through relatives and the local government enabled the local communities to enhance their livelihood activities.

*Perceived effective climate change adaptation strategies according to settlement type and elevation zone*

Among the respondents who perceived their adaptation strategies as effective, more than fifty percent were from the high elevation zone. They reported that the following adaptation measures were a success; water 79 (75 %) and soil 42 (66 %) management strategies, use of different seed varieties of crops 33 (82.5 %) and supplementary feeds 26 (53 %) (Table 5). Fifty-two percent of the respondents from the low elevation zone reported that adopting drought-resistant livestock was effective compared to 48 % in the high elevation zone. A study in central Ethiopia found that the effectiveness of adaptation strategies varied across agro-ecological areas (Etana et al. 2023). The study reported that the most effective strategies in the highland and midland regions were centred on improving selling dairy milk and animal fattening, while in the lowland area, the use of irrigation was found to be the most effective way of mitigating climate change impacts (Etana et al. 2023). Table 5.5 presents the results of the analysis on the effectiveness of the adaptation strategies according to settlement type and elevation zone.

**Table 5.5** The analysis of the effectiveness of the adaptation strategies according to settlement type and elevation zone.

Adaptation measures	ELEVATION		SETTLEMENT TYPE	
	LOW	HIGH	URBAN	RURAL
<b>Water management strategies (105)</b>	26 (25%)	79 (75%)	67 (64%)	38 (36%)
<b>Soil management strategies (64)</b>	22 (34%)	42 (66%)	27 (42%)	37 (58%)
<b>Different seed varieties (40)</b>	7 (17.5%)	33 (82.5%)	11 (27.5%)	29 (72.5%)
<b>Supplementary feeds (49)</b>	23 (47%)	26 (53%)	15 (31%)	34 (69%)
<b>Drought-resistant livestock (31)</b>	16 (52%)	15 (48%)	8 (26%)	23 (74%)

Table 5.5 presents the frequencies and percentages of the respondents who reported the adaptation measures as effective.

Also, there were clear differences between the reports made by the respondents from urban and rural areas regarding perceptions regarding the effectiveness of the adopted adaptation strategies implemented. For instance, coping measures such as soil management measures, use of different seed varieties, use of supplementary feeds and drought-resistant livestock were more strongly perceived as effective measures to climate change impacts by households in the rural areas, where more than fifty percent of the respondents acknowledged the value of these measures. However, adopting water management strategies was perceived as an effective measure in reducing incidents of water shortages more by local communities in the urban areas, where it was reported by 65 % of the respondents. Dilling et al. (2019) state that different perspectives on what defines a risk and how a risk should be mitigated may contribute to different perceptions of adaptation success. Etana et al. 2023 state that the efficiency of adaptation strategies varies depending on specific climate and non-climate contexts. In central Ethiopia, for instance, households with access to livelihood assets effectively mitigated the impacts of climate change by diversifying their adaptation strategies and participating in high-return activities Ethiopia (Etana et al. 2023).

Fifty-eight (16%) of the surveyed households reported that the adaptation measures they had adopted were ineffective. The respondents who reported that the adaptation measures they adopted had not worked for them include, Ladybrand 6 (1.6%), Marquard 9 (2.5%), Vrede 6 (1.6%), and Qwaqwa 37 (10%). Some of the adaptation measures were not successful in reducing the impacts of climate change on the livelihoods of the local communities. This is possibly due to factors identified by respondents as impediments to effective adaptation measures, namely, lack of financial support, lack of resources such as water and land, and social factors such as lack of formal networks. As a result, policies aimed at planning and implementing adaptation programmes should incorporate the socio-economic aspects in climate change adaptation. The veterinary officer from Ladybrand and Marquard said that lack of planning and poor management by the livestock-based households had resulted in low effectiveness in livestock vaccination. Therefore, understanding the factors that impede the effectiveness of the adaptation measures is required so that these factors can be solved to ensure the successful implementation of sustainable measures that can address conditions brought by climate change. According to the respondents, institutional relations between municipal authorities involved in disaster management, waste management, water supply and environmental management departments, Non-Governmental Organisations and local communities, were lacking across the region. According to the interview conducted with the

Environmental Management Officer, limited government involvement and poor implementation of government policies in climate change adaptation and poor access to resources might have heightened ineffective and unsustainable coping and adaptation strategies. However, institutional strategies for dealing with climate change impacts may be restricted due to a lack of capacity of public institutions in terms of available financial, physical, human resources and coordination. Shabani and Pauline (2021) state that effective adaptation strategies require government policies such as the reduction of high agricultural input prices, access to affordable credit, adequate weather information, the availability of water resources, adequate technology, and extension services that create supporting activities and environments that shape the adaptation strategies already implemented.

## **5.7 Conclusion**

The study aimed to identify the most preferred adaptation strategies adopted by the local communities in Thabo Mofutsanyane District Municipality of South Africa, and the extent to which these strategies could be considered effective in building resilient mountain communities. The findings of the research show that local households have adopted several coping and adaptation strategies to curb the impacts of climate change on their livelihoods. Most respondents reported that short-term climate variability affects their livelihoods and have made independent decisions based on the changes they have previously/currently witnessed. According to the findings of the study, various adaptation measures from different households, such as livestock and crop management strategies, water and soil management strategies, formal and informal support, as well as on-and-off-farm diversification strategies, were reported. A significant percentage of respondents reported that the adaptation measures had worked for them in reducing the impacts of climate change on their livelihoods. The adaptation strategies that were reported as effective by the local communities are crop and livestock-based strategies and water and soil management strategies. The study findings show that these preferred adaptation strategies that were reported to be effective by the households are sensitive to the changes in climate. Thus, providing options for non-farm income sources is critical since it will enable local communities to be involved in activities that are least prone to climate change. However, the ineffectiveness of these adaptation tactics reported by some of the sampled households might be linked to socio-cultural, economic, and institutional issues. The high costs of agricultural inputs needed to improve soil fertility, the purchasing of supplementary livestock feeds and water, as well as livestock vaccination lead to elevated cost of food production and affect the well-being of the local communities, as well as food security

and livelihoods. It is, therefore, essential to understand the various factors influencing the adoption of those techniques to enhance the local communities' adaptive capacity. Future climate change adaptation efforts should include the role of socio-cultural, economic, and institutional factors in determining local community decisions to support successful adaptation measures.

### **Study Limitation**

The study contains limitations since the attitudes of the households were analysed based on self-reported responses. Also, the households engaging in backyard gardening did not keep records of crop yields. As a result, responses to the effectiveness of the adaptation measures are likely to be biased, and self-reported behaviour may not correlate to actual observations.

### **Statements and Declarations**

**Conflict of interest:** None

**Competing interests:** The authors have no relevant non-financial/financial interests to disclose.

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**Disclosure statement:** The authors declare there are no competing interests.

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**Data availability:** The datasets collected and analysed during the present study are presented in the main manuscript.

**Code Availability:** N/A

**Ethics Approval:** Prior to the start of the study, an ethical approval was issued from the University of the Free State's General/Human Research Ethics Committee (GHREC) (Ethical Clearance number: UFS-HSD2020/1277/0709).

**Consent to participate:** An informed written consent to participate in the research was obtained from each participant.

## **CHAPTER 6: SUMMARY AND SYNTHESIS OF STUDY**

### **6.1 INTRODUCTION**

As climate change and variability become more prominent globally and in EFSR of South Africa in particular, there is growing evidence of altering weather systems. Farming is the main source of income and livelihood for many communities in the region. Therefore, these aspects of climate change pose the most severe threat to natural resources and livelihoods. Climate extremes seriously affect availability of health, water resources, food security, infrastructure and natural systems (Muyambo et al. 2022).

### **6.2 SUMMARY AND SYNTHESIS**

This chapter summarises the findings of all the analyses done in the study. A combined qualitative and quantitative research methods were used in the study. Chapter 1 introduced the concept of climate change, its impacts on their livelihoods and methods of adaptation in global and African contexts. The problem statement, justification, research aim and study objectives were highlighted, while the organization of the thesis was provided in the conclusion of that chapter. Literature on the impacts climate change on livelihoods, and adaptation measures to mitigate such impacts, were reviewed in Chapter 2. Chapter 3 sought to determine if the climate of the EFSR had changed. This was achieved by analysing the temporal variation of climate variables (temperature and rainfall). Maximum temperatures (Tmax) and minimum temperatures (Tmin) and rainfall climate data were attained from the Climate Explorer's Climate Research Unit (CRU) gridded data file at spatial resolution of 0.5° X 0.5° and analyzed for trends. The chapter presented an analysis of temporal and spatial characteristics of temperature and rainfall over the region. The study also applied the SPI to identify 3-6-month droughts across the region.

#### *6.2.1 Assessment of how the climate of the Eastern Free State Region has changed since 1960.*

Chapter 3 of the study analyzes temperature and precipitation trends in the period 1960-2019 in the sampled towns. The study findings showed that all the sampled towns were exposed to temperature increase, reduced precipitation, and high drought risks in the face of climate change. Temperatures in the study area changed significantly, indicating an increasing trend in mean maximum and minimum temperatures and a decrease in precipitation. The analysis

includes temporal (Figures 3.5, 3.6, 3.7 and 3.9) and spatial (Figures 3.10 and 3.11) maximum and minimum temperature changes observed. The results from the Mann-Kendal (M.K) test showed that maximum and minimum temperatures increased ( $p < 0.05$ ). The results align with those conducted in other parts of South Africa (Dube and Nhamo 2020; Adeola et al. 2022; Sibitane et al. 2022), where maximum temperatures have increased. The SRSD revealed an abrupt shift in both minimum-maximum temperatures and precipitation. These temperature changes negatively impact farming operations and water resources in the region. Exposure to higher temperatures, reduced precipitation, and high drought risk have not only had negative consequences not only in the study area but also in many other parts of the country (Banda et al. 2021; Ndlovu et al. 2021; Shikwambana, Malaza, and Shale 2021; Nkamisa et al. 2022). However, the actual implications of these climatically related severe events remain unknown (Muyambo et al. 2022).

The study reported drought conditions in the region, according to a 3-and-6-month analysis using SPI. The SPIs of the significant drought events in the region were experienced. The droughts during the JFM seasons were primarily moderate to severe, with only a year of extreme drought events. According to the findings, the EFSR faced severe-extreme drought years in 1968, 1973, 1983, 1992, and 2016 for JFM subseason. For the OND season, dominant droughts were reported in the years 1990, 1994, 2011, 2015 and 2019. However, more years of high drought events during OND season occurred from 1990 to 2019 compared to JFM, reflecting high drought years recorded from 1968. This may indicate that the OND season is experiencing more drought periods, and the JFM season is experiencing more wet periods. For the 6-month (ONDJFM) timescale analysis, the SPI identified 1967/68, 2011/12, 2015/16 and 2017/18 as some of the major drought years in the study area. This was consistent with other studies that stated moderate to severe/extreme drought conditions in the Free State province (Abubakar, Scholes, and Newete 2020; Mbiriri, Mukwada, and Manatsa 2019; Orimoloye et al. 2022). It is expected that in future, the severity of droughts will increase in the Free State due to climate change. The increased temperature variability coupled with decreased trends in rainfall could be the significant factors in the occurrence of increasingly frequent droughts locally and in parts of South Africa. According to regional climate model predictions, droughts events are expected to occur more regularly and more severe in this region because of global warming (Orimoloye et al. 2022). The current study suggests further research on different types of droughts, using future projection data of precipitation and temperature. For example, during a prolonged drought in the Free State province, many farming households experienced food

insecurity, malnutrition, and income reductions (Orimoloye et al. 2022). Such further studies could be valuable for planning and formulating drought adaptation or mitigation strategies.

The occurrence of climate variability and extreme events in the study area varied among the elevation zones. The outcomes of the spatial analysis showed that the change in maximum temperatures and rainfall patterns varied across the sampled towns. Regarding the spatial distribution of rainfall, for example, Vrede and Phuthadjithaba which are in the higher elevation zone received more years of high rainfall than those in Marquard and Ladybrand the lower elevation zone .

The majority of households are well-aware of climate variability and change. The study revealed that households had perceived and experienced changes in climate changes (Table 3.3), and their perceptions were similar to the climatic trends. They revealed their local experience of changing climate based on variability in the starting and ending of rainfall, decreased rainfall, increased drought events, and increased summer temperatures. The households' perceptions of climate change were impacted by recent years' experiences. The perception of climate change and its impacts differed for households with different livelihood activities and households' personal experiences with climate change. Specific farming contexts play a role in households' perceptions, with livestock and crop-based farmers in the study reporting different impacts of climate change. Therefore, methods of climate change adaptation that are universal/"one-size-fits-all" and policies that do not consider household heterogeneity are unlikely to be successful.

As demonstrated in Chapter 4, the study unravelled the coping strategies adopted by local communities during climate-related events and the extent to which these responses could be considered effective in building resilient mountain communities. The sources of the data used were interviews held with household heads, two veterinary officers and local government officials. Statistical analysis for survey data included descriptive statistics (frequencies and percentages), logistic regression, Student T-test, and Pearson Correlation. Chapters 3, 4 and 5 reviewed relevant literature and research methods in accordance with the objectives of the study.

*6.2.2. Examination of the effects of climate change and variability on the livelihoods of rural communities in the Eastern Free State Region.*

Climate-related events such as those stated above have negatively impacted the ecological and socio-economic systems across the sampled sites. These include reduced water quality and quantity, crop loss, reduced crop yields, animal diseases, livestock mortality, loss of income, and disruption of essential services observed in Chapter 4. In the study area, erratic rainfall and drought events have caused reduced water availability, accessibility and supply leading to restricted access to water for different purposes. There is a link between climatic and non-climatic factors on water resources (Muyambo et al. 2022). Water scarcity has led to an impact on both on-farm and off-farm livelihoods. Muyambo et al. (2022) state that water scarcity in Qwaqwa is exacerbated by non-climatic factors such as population development, informal settlements, rapid urbanisation, poor infrastructure maintenance, corruption, misconduct of public resources, insufficient funds, and limited skilled expertise. The authors further state that because of these non-climatic factors, it will be harder to reduce climate change effects on water sources and improve community resiliency (Muyambo et al. 2022).

Climate change will continue to negatively affect agricultural productivity and food safety in local communities. The decline in rainfall and droughts over the past 59 years has placed the communities of the EFSR in a vulnerable position because of the impacts of climate change. The findings of the study indicate that shortfalls in the production of vital primary environmental resources affect the overall sustenance of livelihoods in the region. Incidents of crop losses, reduced crop yields, shortage of feed and water for livestock, increasing heat stress, and livestock diseases were the challenges of crop-livestock production in the study area. An earlier study conducted in the Free State province revealed that agricultural lands, and cultivated grasslands were affected by droughts, in the year 2015 (Orimoloye et al. 2022). This negatively affected both crop and livestock farming households in the region, as perceived by the households. Any limits imposed on crop and livestock production indicate that food insecurity and rural poverty will worsen among the local communities that rely on agriculture for their sustenance.

In the current study, the respondents perceived the main socio-economic impacts of climate change to be loss of household income, health problems, additional costs, additional labour, and loss of employment. Only a few respondents experienced health related problems associated with low and high temperatures, heavy rains, and low water quality. However, due to climate change, low crop yields and poor farm productivity resulted in low farm income, leading to low farm profits and a lack of household income. Kalele et al. (2021) state that decreased crop yield caused by poor crop performance results in low on-farm income. Food

prices are high during droughts, resulting in hunger and malnutrition since low-income households cannot afford high food prices (Orimoloye et al. 2022). Lack of alternative sources of income compromised the capacity of households to gain access to a variety of household commodities and to purchase farm inputs. Additional costs mentioned by the households were associated with the purchasing of supplementary stockfeed, drinking water and firewood or gas for heating during cold weather and the replacing of damaged pipes.

### *6.2.3 Evaluate of the effectiveness of the adaptation strategies that have been adopted by the rural communities in addressing the impacts of climate change and variability on rural livelihoods in the Eastern Free State Region.*

The study findings reveal that local communities have put in place specific climate adaptation measures in their attempt to reduce the adverse impacts of changing climate (as highlighted in Chapter 5). The main adaptation measures implemented by the local communities in the EFSR include water management strategies, crop diversification, sourcing of supplementary livestock feeds, use of drought-tolerant livestock, formal support from the local government and informal support from relatives and neighbours. Studies done by Talanow et al. (2020) and Nembilwi et al. (2021) list some climate change adaptation strategies implemented by the communities in South Africa. This could imply that most people in South Africa are facing similar climate-related risks. The present study found that some local communities were implementing combined adaptation measures. Such decisions by the communities could indicate that more than a singular strategy is needed to adjust to climate change impacts. Other coping strategies related to climate change such as altering food intake or changing diet and migration, were implemented less frequently by households.

To mitigate water scarcity related to climate change, the households reported collecting water from relatives or municipal tanks, buying water for drinking, harvesting rainwater and use grey water for gardening. Several studies have reported adopting similar water management strategies (Bedeke et al. 2019; Thinda et al. 2020; Kalele et al. 2021). According to Apraku et al. (2023), availability of clean water is not guaranteed throughout the year due to fluctuating global climate conditions, with humans and livestock having to access water from the same sources.

Responses to reduced crop loss and yield included abandoning some crops, adopting drought or frost-resistant crop varieties, and crop diversification. These measures adopted by the households were designed to enhance crop productivity in the face of changing environment

and socio-economic systems. The soil management strategies mentioned by the farmers included using inorganic and organic fertilizers which helped improving soil fertility and structure, increase soil moisture, and improve yields. Several studies have shown the importance of using manure and inorganic fertilizers in enhancing soil fertility, soil moisture content and crop yields (Henningsen et al. 2020; Kalele et al. 2021).

Households diversified into different forms of off-farm income due to perceived effects of climate change related to poor yield and reduced on-farm income. The findings of the study show that the households' livelihoods had become more diverse by moving away from sole reliance on agriculture and toward other sources of income. These diverse measures included petty trade, leasing land, selling non-agricultural produce, borrowing money, selling labour, catering at events, operating driving schools, and construction-related activities. These findings are consistent with other studies reporting livelihood diversification activities to deal with climate change and variability (Call, Gray, and Jagger 2019; Yiridomoh, Sullo, and Bonye 2021; Sertse et al. 2021). However, this study suggests that off-farm work opportunities still need to be improved, especially for households in rural areas. Climate change adaptation through informal support from relatives and friends, and formal support from the government was reported by households. Informal support involved the provision of temporary jobs, borrowing money, income and sharing labour from neighbours or relatives, receiving assistance by providing food, water, livestock feeds, livestock manure, and rendering labour to affected families.

The results showed different adaptation strategies used by the local communities across the two elevation zones and settlement types. The findings revealed some similarities and differences in the adaptation measures taken by local household members across the two elevation zones. Adaptation strategies such as water management tactics, crop diversification, soil management, and formal support were frequently reported across the two elevation zones. It can be concluded that since management practices differ, households must therefore implement them according to their local environmental conditions and farming practices. Results demonstrate that in the EFSR, the susceptibility to climate change differs depending on the degree of exposure of the impacted communities and the adaptive capacity of these communities. Household based climate adaptation strategies can be improved by increasing indigenous knowledge of climate predictions, improving traditional methods of land and

environmental conservation, and conducting more studies on different crop varieties and soil in diverse agro-ecological regions (Maliki and Pauline 2022).

Having identified the strategies employed, the extent to which these strategies could be considered effective in building resilient mountain communities needs to be examined. According to Williams et al. (2021), conducting an in-depth evaluation of the effectiveness of practices would reveal low-cost practices and other factors that provide better and more detailed information for decision support. These strategies include water and soil management strategies, using different seed varieties, purchasing supplementary feeds, and adopting drought-resistant livestock. This study demonstrates that evaluating effectiveness of identified climate adaptation practices could guide informed planning and actions among stakeholders and consequently inform policy on climate adaptation. However, the effectiveness of these measures varied amongst local communities depending on the types of livelihood activities, climate implications they faced, and measures undertaken to alleviate these impacts. One reason for differences in household perceptions of the success of some adaptation measures was that the impacts of climate change differed across the district, and various households were affected differently depending on the type of livelihood activities.

In conclusion, this study has revealed that rainfall patterns and temperature have become highly variable. The frequency of drought events adversely affects the livelihood of local communities in the study area. Evidence from the study indicates that there are attempts by households to introduce adaptation strategies in order to adapt to climate change and variability. However, lack of adequate information about climate variability and change often results in practices that lead to maladaptation. The study findings reveal that climatic trends and local climate knowledge guide autonomous adaptation measures that could mitigate climate change impacts and improve resilience within local communities. More specifically, the socio-economic context, geographic and climatic conditions prevailing in the study area, and settlement type could be considered in the identification of adaptation practices.

## **CHAPTER 7: CONCLUSION AND RECOMMENDATIONS**

### **7.1 INTRODUCTION**

Chapter 7 presents the conclusion of the study. It highlights the contribution of the research to the existing body of knowledge, presents recommendations from the thesis and identifies areas that require further research. Due to the differing nature of climate change impacts, it is crucial for local communities in the EFSR to adopt adaptation measures that are site-specific, taking into account the socio-economic conditions that prevail in their environment. Without such an approach, the use and importation of strategies without evaluating their potential effectiveness in specific areas will have negative effects on the environment and the communities involved. Taking this reality into consideration, the research adopted the SLF proposed by the Department for International Development. The SLF framework was used as a guide for the preliminary investigation that was conducted. The SLF effectively explained the environmental and socio-economic factors affecting the local communities in EFSR under threats from climate change based on altitude and settlement type. The study highlights how the climate (temperature and precipitation) of the EFSR has changed over the years. The study also assessed the perceptions of the local communities, the opinions that these communities held on climate variability and change implications on their livelihoods, and the coping measures they adopted. The focus of the thesis was to assess the strategies that rural communities have adopted in the EFSR of South Africa to decrease the vulnerability of their livelihoods to climate change.

The research was guided by four objectives, namely:

1. To assess how the climate of the Eastern Free State Region has changed since 1960.
2. To examine the effects of climate change and variability on the livelihoods of rural communities in the Eastern Free State Region.
3. To evaluate the effectiveness of the adaptation strategies that have been adopted by the rural communities in addressing the impacts of climate change and variability on rural livelihoods in the Eastern Free State Region.
4. To draw up recommendations that could inform sound policy measures and future strategies that seek to maintain sustainable rural livelihood adaptations without degrading the environment in the region.

## 7.2 CONCLUSION

Based on the analysis of the climate data, the following are key findings of the study.

1. The study revealed that the climate of the EFSR has changed since 1960. This study revealed that maximum and minimum temperatures both increased substantially between 1960 and 2019, while precipitation decreased during the same period. Temperature and rainfall are key climate variables that determine agriculture-dependent livelihoods. The trends in temperature and precipitation have implications for agricultural activities as the region's agriculture is primarily rain-fed and subsistence in practice. Such changes adversely affect yields and quality of produce and further degrade the socio-economic conditions of the local households. The reduced yield further means reduced access to food, increased prices, and reduced income, thus threatening food security, especially for low-income groups.
2. There is an increased incidence of severe weather incidents, as indicated by the SPI values. The SPI values for the JFM and OND sub-seasons and the ONDJFM season indicate that in the EFSR, there was a prevalence of severe drought for several years. The recurrence of negative SPI values in the time series might signify increasing aridity in the region. The results show more years of drought during the OND season compared to the JFM sub-seasons. This is especially important the OND period is the growing season and droughts can be devastating when they coincide with the growing season. This implies that events of droughts and low rainfall during sowing or early stages of growth may negatively affect crop yields. Droughts will affect the hydrology of some water sources, thereby impeding the implementation of irrigation techniques as one of strategies for adaptation to climate change impacts. The increased variability in the climate means increased pressure on livelihoods as they suffer shocks with the increasing intensity and regularity of extreme climate events, in this instance indicated by the prevalence and intensity of droughts.
3. Comparing household perception with observed climatic trends revealed a close and consistent match. The findings indicated that majority of communities in the EFSR were aware of climate change and its impacts on their livelihood activities. Awareness of climate risk changes helps households apply specific changes to their livelihood patterns that coincide with climate variability and extreme weather conditions. Therefore, it can be concluded that integrating communities' perceptions and local knowledge about climate change with accessible scientific knowledge could build capacity for global climatic change adaptation and mitigation. It is critical to note that interventions cannot only stop at information access as this

will likely not solve the challenges communities face but enhanced capability and inbuilt resiliency to climate change and variability effects will. While households are aware of climate variability, the local people have been failing to address these changes effectively. In this case, they had the relevant climate information but did not have the capacity and resources to cope and operated at scales that the adoption of specific measures was not feasible or cost-effective. It is important that while measures should take into account people's perceptions, indigenous knowledge and scientific knowledge, the socio-economic condition of the communities is often also a critical factor in the adoptability of any intervention.

4. According to the households' perceptions, most respondents reported that they had stopped some climate-related livelihood activities as a result of climate change. This is not the best option for communities that heavily rely on farming, like those in the EFSR, because any reduction in activity also results in a reduction in the capacity of the household to provide food and nutrition for its members. The cessation of climate related livelihood activities makes it difficult for communities to adapt to climate change since it undermines household food security. Local communities lacked control over climate-related changes, hence they also lacked the capability to put precise plans into place to address the problem. Cessation of climate related livelihood activities has led to the abandonment of on-farm activities and adoption of off-farm livelihood activities. Greater monitoring of weather can help communities in knowing when they can fully pursue farm activity and when to scale back. Such an approach will reduce household losses in especially dry years where losses can be great and cause communities to abandon agriculture-based economic activity.

5. Local communities that practised rain-fed agriculture and those that depended on open water sources for domestic purposes suffered the consequences of increased water shortages due to a significant decline in water availability. Water scarcity has had implications for socio-economic systems in the region. However, in addition to climate variability, water shortages have been caused by inadequate government support, poor reservoir management, or a lack of investment in water storage bodies amid the increasing population. It can be concluded from the results that communities in the EFSR are faced with severe water shortages due to climatic factors and non-climatic variables.

6. The results showed that local communities have adopted several adaptation strategies that enable them to cope with food insecurity, including those aimed at reducing dependence on on-farm activities for livelihood. It is important to note that most measures adopted were short-term rather than long-term. The local communities preferred to act on immediate or current climatic outcomes. Their actions were based on the need to ensure short-term survival rather

than a concerted effort to develop strategies that were more adaptable to a changing climate in the long term. For instance, results indicate that local communities preferred to alter to the changes in rainfall patterns and droughts that they had observed during the past 5-10 years rather than long-term changes. As a result, long-term adaptation measures have not been given any priority by the local communities.

7. As the climate has changed, people tend to move from on-farm to off-farm activities as a mitigation response to variable climate conditions. Off-farm activities were dominated by self-employed-based activities cited in the study. These findings suggest that livelihood diversification was used as an approach to reduce household susceptibility to climate change. However, the success of off-farm activities in comparison to historical on-farm activities is debatable. Off-farm activities often require higher investment costs and increase risk in poor households and their ability to allocate scarce resources efficiently. Based on the profile of the farmers, it is worth mentioning that most of the households were from low-income groups, with limited means and capacity to invest. Hence, the burden of meeting the costs of such measures end up being borne by the government and other institutions rather than by the beneficiaries of the activities. Any inefficiency in programmes supporting such activities has a detrimental effect on household livelihood. In cases where strategies employed work, there is also a need for household income diversification as some off-farm activities include seasonal work. In the absence of those off-farm activities, communities still needed economic activity, and as such, re-establishing on-farm activities, even on a small scale, should aid livelihoods. However, there were challenges in identifying ideal strategies and often, even if correctly identified, lack of capacity was a huge barrier. What is clear is that resource-constrained households will require the support of the government and other institutions in order for them to adopt and implement effective climate change adaptation strategies.

8. Certainly, strategies that are seen to be more effective are more likely to be adopted. A significant percentage of the respondents reported that some of the adaptation measures were effective as they noticed results in increased crop yield, improved soil fertility, reduced water problems, and improved livestock health from the different livelihood outcomes. The findings of the study show that the preferred adaptation strategies reported to be effective by the households are sensitive to the changes in climate. However, such strategies are ineffective due to abrupt climatic adjustments that catch communities off guard and expose them to the consequences of these shifts. Also, the high costs of agricultural inputs needed to improve soil fertility, purchasing of supplementary livestock feeds and water, as well as livestock vaccination led to an elevated cost of food production, affecting the well-being, food security

and livelihoods of the local communities. Thus, providing options for non-farm income sources is critical since it will enable local communities to engage in less climate-sensitive activities. For better performance, indigenous coping and adaptation measures need further scientific support and economic assistance from government and non-government organizations. While implementing these adaptation measures could improve crop and livestock production, a high number of respondents who depended on these measures were primarily motivated by the ability of each strategy to increase household income and profit rather than its environmental benefits. This argument suggests that assessing both the economic and environmental effectiveness of identified adaptation strategies is imperative for enhancing adaptation planning and actions implemented by low-income households. Due to the limited resources of most households, it is pivotal to explore the economic effectiveness of identified adaptation practices that are affordable and cost-effective.

### **7.3 RECOMMENDATIONS**

Based on the study findings, the following recommendations are proposed:

1. Monitoring and evaluation of weather patterns in the region. Providing access to climate information can help improve resilience and decision-making in the context of environmental change and severe climatic events. Villavicencio et al. (2022) state that the availability of meteorological information in mountainous areas is difficult because of inadequate weather stations. This study, therefore, recommends that local weather stations be installed. This will help the region to access short-term weather forecasting/prediction and improve disaster risk reduction. Investments in early warning systems from the Department of Disaster Risk Management can support vulnerable communities to prepare for anticipated changes and, in so doing, protect their livelihoods and assets. There is need to create better monitoring systems that can detect short term weather changes since it will aid in planning farm activities and minimize crop losses.
2. Local communities in the EFSR can consider reducing the impact of late rainfall onset on their agricultural activities by growing drought-resilient crops during the earliest sub-season rather than waiting until the late sub-season to irrigate. With increasing aridity the variety of crops planted will have to change in line with changing climate, with more drought resistant crops accorded better consideration. Within season variations in this case means even when normal rainfall is received, its distribution across the season can impact

crop yields. By adapting seed varieties that can withstand prolonged dry spells, yields can be maintained at a level that does not make households totally shift to off-farm activities.

3. Since the study findings suggest that due to climatic variations in the study area, both off-farm and on-farm adaptation approaches need to include local settings to promote suitable coping and adaptation measures, households must implement measures according to their local environmental conditions and livelihood practices. More focus should be on implementing adaptation plans on a local scale. For example, the ability to implement coping measures suitable for a specific area, such as changing sowing dates, changing crop species, changing cropping patterns, and employing crop rotation, might enhance crop production, ensure food security, and sustain land productivity. Mixed farming methods will strengthen the resilience of crop-and livestock-based households to climate change and variability.
4. Building on existing coping strategies to support adaptation may contribute to overcoming prevailing food insecurity challenges in resource-constrained region while supporting sustainable future crop production. This can be done through investments in long-term adaptation measures such as crop diversification, agricultural insurance, access to credit, agricultural investment in research and extension services, and strengthening policies that support the resilience of communities to climate risks; that will complement the already existent short-term measures.
5. Keeping different livestock species is a strategy that can be applied to increase economic and social resilience to climate change. Herd diversification is an adaptive strategy that could be introduced as insurance against hot environmental conditions due to increased summer temperatures and the outbreak of climate-related diseases. It will help with utilization of pastures and prevent selective overgrazing. Strict disease management programmes should be explored to improve livestock health.
6. Communities must consider alternative grazing systems and feeding options to improve fodder availability. As such, extension officers from the Department of Agriculture and Rural Development need to train farmers to implement sound feeding systems. It is recommended that further studies be done on how to make animal feeds that are affordable and nutritious, using locally available resources to the local communities, such as hay, crop residues, and maize silage.
7. Water sources, such as rivers, dams, ponds, and wetlands, must be properly managed to decrease water shortages resulting from drying sources due to hot environments, erratic rainfall, and

droughts. Policymakers from the Department of Water and Sanitation should build infrastructure to help the local community adapt to climate change. Such investment in infrastructure should include the construction of artificial ponds and storm drainage and promoting renewable energy technologies like wind energy and solar energy. Advice should be given to local municipal officials to maintain drainage systems and roads to reduce the risks of flooding in the event of heavy rains.

8. Most of the local communities have reported water shortages for more than five years as the main problem for their livelihood activities. Hence, it is important that municipal water management approaches be more concerned with the long-term sustainability of water resources, like managing the existing water, treatment and water reuse, and groundwater development. Municipal officials should work closely with the local communities to understand their views regarding climate-related water stress and how climate change adaptation can best be implemented within the context of water management. The households' perceptions might assist policymakers to understand what needs to be done to implement sustainable water management practices in the midst of climate change. The study findings show that access to more than one water source likely reduces climate change vulnerability among local communities. Therefore, the study recommends that households receive government support regarding the diversification of water sources to enable them to adapt to climate change impacts. The local authorities tend to focus on providing access to water in urban areas, with less provision in rural areas. Hence, government facilities should provide sustainable water sources to the communities irrespective of their settlement type. Further implementations should focus on strategies and practices of everyday water access, especially in rural-based households. There is a need for investment to supply water to rural users, which may be expected to improve their livelihoods (economic and social values).
9. Access to extension programs for agriculture is an important source of knowledge on climate change, adaptation to climate change, and agricultural management practices. These strategies could improve accessibility to and utilization of proper agriculture inputs, market information, crop diversification opportunities, irrigation systems, livestock vaccinations and climate-smart agricultural technologies.
10. The study recommends that local communities be advised to adopt agroforestry practices by growing indigenous plants and/or fruit trees in their homesteads to regulate temperatures, reduce soil erosion, and provide livestock fodder and manure.

11. The environment in the EFSR is continuously getting drier, and the regular coping measures that might have been applicable or effective in the past years might not be appropriate to the current changing conditions. Therefore, the study recommends the evaluation of the adaptation strategies that the local communities have introduced over the past years and alternative coping measures that can be introduced in the area.
12. The study suggests that local governments ensure the active community participation in policy design and implementation. Local policies must incorporate climate change adaptation strategies into their annual plans. Moreover, adaptation strategies should integrate environmental, sociocultural, and economic aspects to ensure their effectiveness and a better outcome. Finally, it is crucial to integrate local communities' traditional knowledge with modern technologies for effective and sustainable outcomes in the long run.
13. Environmental programs and awareness on the effects and causes of climate change ought to be improved and offered to the local people to avoid the exacerbation of its effects and enhance the implementation of adaptation plans. The study recommends that environmental public awareness and education should be improved, particularly in rural populations with misunderstandings and lack of capacity to respond to climate change. It is also recommended that local communities should be given accurate and timely information about predicted climatic changes in order to adjust their farming practices appropriately.

### **Recommendations for areas of future research:**

The perceptions of the households were examined based on self-reported responses to understand the different perceptions. In some way, the households' responses were likely to be biased because self-reported behaviour may not correspond to actual behaviour. Hence, future research should analyse actual household behaviour in relation to climate perceptions to derive actual adaptive household livelihood activities. This can be achieved by direct observation and partnering with local governing structures to consider the biophysical and socio-economic conditions under which communities operate in order to develop effective adaptation techniques tailored to the local context.

Although the study has provided key information regarding climate change perceptions, impact, and adaption strategies, the SLF approach used had limitations in adequately unveiling the relationships between variables and climatic and non-climatic factors. For example,

additional research is required to find out the relationship between water availability and climatic and non-climatic factors using a more robust framework or approach. Climate and non-climatic factors might have altered the hydrological system in the region over the years, urging a need to assess the historical changes and future projections of water availability. This could involve an analysis of the correlation between water availability and climatic factors such as precipitation, temperature, and droughts using the Standardised Precipitation-Evapotranspiration Index (SPEI). Similarly, analysing the relationship between water availability and non-climatic factors namely population increase and land-use and landcover changes is necessary. Determining the connection between each of these factors or the combined impact on water availability may help in climate risk mitigation strategies, thus increasing water availability to the local communities and agricultural farming, hence safeguarding agricultural productivity in the district.

While the study acknowledges that adaptation efforts such as water management measures and crop diversification are already in place, it suggests that future research should take a step further in improving adapting measures, so as to reduce the negative impacts of climate change on household livelihoods. Long-term adaptation measures need to be considered to deal with future climate change, which include crop diversification, agricultural insurance, access to credit, agricultural investment in research and extension services, and strengthening policies that support the resilience of communities to climate risks. Adaptation measures such as crop diversification will require a comprehensive understanding and investments in drought or frost-tolerant crops. Therefore, it is imperative for the local households depended on on-farm income to access frost-resistant/drought-resistant seed varieties so that they get enough agricultural products to sell all year round. When the local communities grow crops throughout the year, not only will they improve food availability but also increase their source of income, and hence their livelihood sustenance.

The absence of government involvement and inadequate implementation of government policies in climate change adaptations and limited access to resources heightened ineffective and unsustainable coping measures and adaptation methods in the region. Hence, this study recommends that in-depth studies focused on holistic scientific approaches be considered, which include educational initiatives within the local communities and institutions to raise awareness and share knowledge, training, and workshops. Workshops should be conducted to teach the households dependent on farming for their livelihood about climate change and its associated effects on crop and livestock farming, how to interpret raw climate data and how to

cope with climate-related impacts. For example, livestock-based households need to be trained so that they have information about livestock vaccination and its importance, and proper feeding systems. Future research is recommended to examine how the communities can access water for their livestock and animal feeds that are affordable and nutritive, using resources that are locally available to the communities.

Local communities face numerous livelihoods security challenges from climate variability, socio-economic factors, population growth, and political difficulties. Future study is recommended to concentrate on determining the magnitude and scale of these multiple factors that affect livelihood security. This could include investigating how other climatic and non-climatic factors influence livelihood activities in the region. If the climatic factors were used conjunctively with non-climatic factors, an in-depth understanding of the factors affecting the households' livelihoods and economy in the region could be enhanced, hence helping towards disaster preparation and mitigation.

#### **7.4 Contribution of the study to the existing literature**

The study explored the spatial variability and temporal trends of maximum and minimum temperatures and rainfall for the period between 1960 and 2019. The research addressed the knowledge gap related to inadequate data and information on climate variability and change in mountainous communities of the EFSR of South Africa. As a result of limited data on mountainous regions, there are very few studies that have incorporated household perceptions into climate change studies especially in the mountainous region (Schneiderbauer et al. 2021). Responses from the questionnaire survey demonstrated that the respondents' perceptions on climate change and variability were compatible with the scientific evidence derived from the climate data. This confirms the view that local knowledge systems can be useful in the validation of information from scientific research findings in environments where there is paucity of climate data. This is particularly significant in mountain areas where climatic data is lacking due to sparsity of weather stations.

A limited range of studies have been conducted to examine the perceptions of local communities on climatic trends across different elevation zones (Schneiderbauer et al. 2021). The findings of this research study have demonstrated how the nature of household perceptions' regarding climate variability and change varied across elevation zones. This research also revealed that household perceptions on climate type vary according to settlement type. The livelihood activities of rural communities are more vulnerable to climate change

compared to those undertaken by urban communities. This information is crucial for climate change adaptation decision-making and planning when designing sustainable livelihood strategies for mountain environments.

Even though there is a large body of literature addressing climate change impacts on livelihoods in general, there has been a lack of evidence on differential effects of climate change on on-farm and off-farm livelihood strategies in communities living in mountain environments. Research on socioeconomic implications of climate change at household level has mainly gone unnoticed (Call et al. 2020), particularly in mountainous regions. Using empirical data, this study investigates household views of climate change and its implications for the on-and off farm livelihood activities, and socio-economic systems. Resource-poor households in the EFSR are particularly exposed to climate change, which affects livelihood and food security, worsening poverty.

It is likely that when households have access to sustainable water resources, individuals can easily access on-farm and off-farm livelihood activities. This research study has established that water scarcity due to rainfall pattern changes is an important environmental factor driving livelihood strategies. Though some researchers have recently reported that lack of water to households is likely to vary according to environmental, socio-economic, and political-institutional contexts, there have been few studies on non-climate factors and water availability (Teng et al. 2022). According to Moshizi et al. (2022) assessing vulnerability to water scarcity due to natural and human-induced factors is complex. Therefore, this research suggests that more work needs to be done to explore non-climatic factors that influence water availability and its role in selecting livelihood options.

Extended periods of water shortages induced by climate change are associated with reduced farm income and increased labour, which may prevent individuals from pursuing off-farm livelihood options. The study suggests that water demands have not been met in the study area due to increasing socio-economic development, coupled with decreasing streamflow resulting from increased temperature, decreased precipitation or droughts. The findings of this research study show that an understanding of a combination of environmental, political, and socio-economic factors is crucial for developing climate change and variability adaptation strategies.

Different households perceive climate change, and its implications differently according to the altitudinal zones in which they live. From the findings of the study, it is clear that households from lower elevation zones are affected the most by hotter environmental conditions and

reduced rainfall and associated problems. The research underlines the value of local contexts and demonstrates the need to avoid broad generalizations about climate change implications, particularly in mountainous places (Spies 2020). This implies that local communities in different elevation zones require more targeted adaptation measures to mitigate the effects of temperature and precipitation changes.

The study observed that short-term measures based on current environmental changes have been prioritised by the local communities. However, in this current context of global environmental change, it is vital to consider that these short-term approaches may no longer be sufficient to sustainably maintain the communities' livelihoods. What remains uncertain is the effectiveness and long-term change of local community adaptation methods in the face of climatic change and variability. Few studies have adequately explored this avenue, regarding evaluating the effectiveness of adaptation methods used by communities (Nembilwi et al. 2021). This study assessed the extent to which the adaptation measures can be considered as effective in building resilient mountain communities. The research findings should provide valuable information for evaluating the effectiveness of current climate change adaptation strategies implemented by local communities in the mountainous areas. The results from the assessment of adaptation strategies indicated that the combination of management strategies provided a better and more efficient solution to livelihood implications arising from climate change. However, the adaptation measures that were considered effective were sensitive to climate change. Therefore, more work needs to be done to help households dependent on on-farm income cope with changes in climate variability and natural disasters (drought, floods) now and in the future. The findings of the study provide insight for policy makers on the most appropriate strategies to be implemented to ensure future water resources and agriculture in the face of climate change.

## **7.5 LIMITATION OF THE STUDY**

The limitations of the current study are as follows.

1. The first limitation is the difficulty of providing a thorough analysis of the effectiveness of the implemented adaptation measures due to time. Owen (2020) argues that the challenge of evaluating adaptation is that climate change operates on longer timescales than many other processes. Therefore, assessing the effectiveness of the adaptation measures could require a longer duration and more robust analysis of the adaptation measures employed by the sampled households in the next 5-10 or more years. For example, it could be helpful to analyse the

implementation of adaptation measures over a certain period of time. This would provide a baseline for future observations and sustainability evaluations by both the communities and various stakeholders. Also, it is important that the local communities are taught about designing effective measures that will align their operations with the changing climate. The study contains limitations since the attitudes of the households were analysed based on self-reported responses.

2. The households engaging in backyard gardening did not keep records on crop yields. As a result, responses to the effectiveness of the adaptation measures are likely to be biased, and self-reported behaviour may not correlate with actual observations.

3. The increased temperature variability, coupled with decreased rainfall trends, could be significant factors in the occurrence of increasingly frequent droughts within the study area. However, the current study did not include analyses of different types of droughts based on the SPEI, which puts the impacts of both precipitation and temperature changes into consideration.

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## **LIST OF APPENDICES**

### **Appendix 1**

#### **RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM**

**DATE**

October 2020

**TITLE OF THE RESEARCH PROJECT**

*Dynamism of rural mountain livelihoods under a changing climate: The case of the Eastern Free State Region of South Africa.*

**PRINCIPLE INVESTIGATOR / RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):**

LOKUTHULA MSIMANGALOKUTHULA MSIMANGA                      2017494408  
07348933950734893395

**FACULTY AND DEPARTMENT:**

FACULTY: NATURAL AND AGRICULTURAL SCIENCE FACULTY: NATURAL AND AGRICULTURAL SCIENCE  
DEPARTMENT: GEOGRAPHY DEPARTMENT: GEOGRAPHY

**STUDY LEADER(S) NAME AND CONTACT NUMBER:**

PROFESSOR GEOFFREY MUKWADA PROFESSOR GEOFFREY MUKWADA  
058 718 5476 058 718 5476

**WHAT IS THE AIM / PURPOSE OF THE STUDY?**

The aim of the study is to examine the impacts of climate change and variability on livelihoods and to assess the strategies that have been adopted by rural communities to reduce the vulnerability of their livelihoods to the changing climate. The aim of the study is to examine the impacts of climate change and variability on livelihoods and to assess the strategies that have been adopted by rural communities to reduce the vulnerability of their livelihoods to the changing climate.

**WHO IS DOING THE RESEARCH?**

Student name is Lokuthula Msimanga and I work under the supervision of Prof G. Mukwada. There is scarce information available on the effects of climate change and variability on rural livelihoods, particularly in the mountain regions of the Eastern Free State Region. The results of the study may provide valuable information that could be used for developing sustainable climate change adaptation strategies and recommendations to the communities in this region.

**HAS THE STUDY RECEIVED ETHICAL APPROVAL?**

This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

**Approval number:** *Insert approval number Insert approval number*

**WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?**

The participants were chosen because of the relevant knowledge they have relating to the livelihood changes they have experienced due to the environmental shifts and the adaptation strategies implemented. The number of participants is approximately 360. The participants were chosen because of the relevant knowledge they have relating to the livelihood changes they have experienced due to the environmental shifts and the adaptation strategies implemented. The number of participants is approximately 360.

**WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?**

The study involves questionnaires survey. The questions will consist of the participant's household information, how changes in climate have affected their livelihoods and what coping measures were implemented to mitigate the impacts. The time allocated to conduct interviews approximately be 30minutes. o conduct interviews approximately be 30minutes. The study involves questionnaires survey. The questions will consist of the participant's household

information, how changes in climate have affected their livelihoods and what coping measures were implemented to mitigate the impacts. The time allocated t

#### **CAN THE PARTICIPANT WITHDRAW FROM THE STUDY?**

Participation in this research is voluntary and that there is no penalty or loss of benefit for non-participation. Being in this study is voluntary, and the participant is under no obligation to consent to participation. If the respondent does decide to take part, they will be given this information sheet to keep and be asked to sign a written consent form. The participant is free to withdraw at any time and without giving a reason. ke part, they will be given this information sheet to keep and be asked to sign a written consent form. The participant is free to withdraw at any time and without giving a reason. Participation in this research is voluntary and that there is no penalty or loss of benefit for non-participation. Being in this study is voluntary, and the participant is under no obligation to consent to participation. If the respondent does decide to ta

#### **WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?**

Taking part in this study might provide opportunities to the participants to join league of people that provide novel information and solutions to build resilience in our socio-ecological systems. The number of participants is approximately 360. Taking part in this study might provide opportunities to the participants to join league of people that provide novel information and solutions to build resilience in our socio-ecological systems. The number of participants is approximately 360.

#### **WHAT IS THE ANTICIPATED INCONVENIENCE OF TAKING PART IN THIS STUDY?**

There are no anticipated risks, harm and or discomforts because their choice of participation will be based on their personal interest and conveniences. There are no anticipated risks, harm and or discomforts because their choice of participation will be based on their personal interest and conveniences.

#### **WILL WHAT I SAY BE KEPT CONFIDENTIAL?**

The information captured will be strictly kept confidential. The identity of the participant will not be recorded anywhere and no one will be able to connect you to the answers you give. Your answers will be given a fictitious code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. The responses given will be reviewed by people responsible for making sure that research is done properly, including the transcriber, external coder, and members of the Research Ethics Committee. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records. The anonymous data recorded may be used for other purposes, e.g. research report, journal articles, conference presentation. you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. The responses given will be reviewed by people responsible for making sure that research is done properly, including the transcriber, external coder, and members of the Research Ethics Committee. Otherwise, records that identify you will be

available only to people working on the study, unless you give permission for other people to see the records. The anonymous data recorded may be used for other purposes, e.g. research report, journal articles, conference presentation. The information captured will be strictly kept confidential. The identity of the participant will not be recorded anywhere and no one will be able to connect you to the answers you give. Your answers will be given a fictitious code number or a pseudonym an

#### **HOW WILL THE INFORMATION BE STORED AND ULTIMATELY DESTROYED?**

The hard copies of your answers will be stored by the researcher for a period of five years in a locked filing cabinet for future research or academic purposes. The electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval to data will be subject to further Research Ethics Review and approval. The hard copies of your answers will be stored by the researcher for a period of five years in a locked filing cabinet for future research or academic purposes. The electronic information will be stored on a password protected computer. Future use of the s

#### **WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICPATING IN THIS STUDY?**

No payments or rewards are offered, financial or otherwise. Any costs incurred by the participant should be explained and justified. No payments or rewards are offered, financial or otherwise. Any costs incurred by the participant should be explained and justified.

#### **HOW WILL THE PARTICIPANT BE INFORMED OF THE FINDINGS / RESULTS OF THE STUDY?**

If you would like to be informed of the final research findings, please contact Lokuthula Msimanga 0734893395 email address sdue89@gmail.com. The findings through the thesis are accessible online from year 2022. If you would like to be informed of the final research findings, please contact Lokuthula Msimanga 0734893395 email address sdue89@gmail.com. The findings through the thesis are accessible online from year 2022.

**Thank you for taking time to read this information sheet and for participating in this study.**

#### **CONSENT TO PARTICIPATE IN THIS STUDY**

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

I have read (or had explained to me) and understood the study as explained in the information sheet. I have had sufficient opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable). I am aware that the findings of this study will be anonymously processed into a research report, journal publications and/or conference proceedings.

I agree to the recording of the questionnaire.

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

Full Name of Participant: \_\_\_\_\_

Signature of Participant: \_\_\_\_\_ Date: \_\_\_\_\_

Full Name(s) of Researcher(s): \_\_\_\_\_

Signature of Researcher: \_\_\_\_\_ Date: \_\_\_\_\_

## **Appendix 2**

### *Acceptance Letter*



MASEPALA WA SELEHAE – LOCAL MUNICIPALITY – PLAASLIKE MUNISIPALITEIT  
Tel: 058 718 6616 / 3767 Fax: 058 718 1777 e-mail: mmadmin@map.fs.gov.za

**OFFICE OF THE MUNICIPAL MANAGER**

Lokuthula Msimanga  
Qwaqwa Campus  
Private Bag X13  
Phuthaditjhaba  
9866

26 August 2020

**Re : PERMISSION TO CONDUCT RESEARCH IN RURAL COMMUNITIES OF  
MALUTI -a- PHOFUNG MUNICIPALITY**

Your letter dated 24 August 2020 received has reference:

Your request for permission to conduct research in rural communities of Maluti -a- Phofung for PhD degree in Environmental Geography at the university of the Free State (Qwaqwa Campus) is hereby granted. The municipality will avail relevant officials to assist you with any available information related to your study, after receiving request for information at least three (3) working days in advance and such information is approved by the Municipal Manager before provided.

For any information pertaining to your research please contact Mr M.S Nhlapo (Manager Environment and Waste Management).

The municipality wishes you all the best in your studies.

Regards  
  
F.P. MOTHAMAHA  
MUNICIPAL MANAGER

MALUTI-A-PHOFUNG LOCAL MUNICIPALITY • Crn Moremohaha & Mofoung Street • Private Bag X 806 • WEINESHOEK 9870  
Tel: +27 (0)58 718 3700 • Fax: +27 (0)58 718 3775/7 • 086 696 2056

### Appendix 3

#### *Ethics Clearance*



**GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)**

08-Sep-2020

Dear Ms Lokuthula Msimanga

**Application Approved**

Research Project Title:

**Dynamism of rural mountain livelihoods under a changing climate: The case of the Eastern Free**

**State Region of South Africa**

Ethical Clearance number:

**UFS-HSD2020/1277/0709**

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical

clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. Furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an

extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and

success with your research.

Yours sincerely

**Dr Adri Du Plessis**

**Chairperson: General/Human Research Ethics Committee**

205 Nelson Mandela  
Drive  
Park West  
Bloemfontein 9301  
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Tel: +27 (0)51 401  
9337  
[duplessisA@ufs.ac.za](mailto:duplessisA@ufs.ac.za)  
[www.ufs.ac.za](http://www.ufs.ac.za)

## Appendix 4

### *Questionnaire Survey*

Questionnaire No

---

Name of Village/Area

---

#### Gender of Respondent

Female

Male

#### Household head

Male

Female

#### Age of Respondent

<30

31-40

41-51

51-60

>61

#### Race of Respondent

White

Black

Colored

Other (s)

**Other (s), please state**

---

**Please state your highest level of education qualification**

- have never received any education at all
- Less than grade 7
- Grade 7
- Matric
- Tertiary (Diploma/ Degree)

**Number of household members**

- 1-5
- 6-10
- 11-15
- 16-20
- >21

**For how long have you been resident in this community**

- <5
- 6-10Yrs
- 11-15Yrs
- 16-20Yrs
- >21

**Employment status**

- Unemployed
- Employed
- Self-employed
- Temporarily employed
- Retired

**Please list the main livelihood activities of your household**

---

**Location**

latitude (x.y °)

---

longitude (x.y °)

---

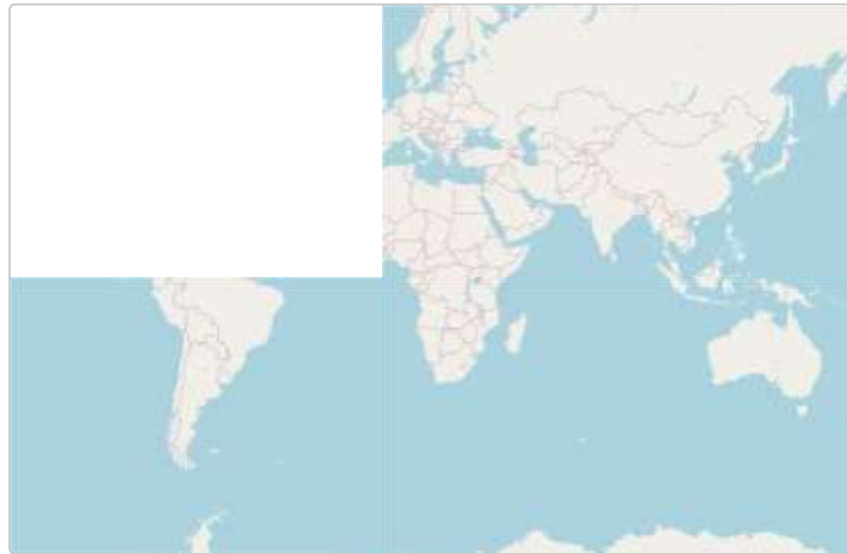
altitude (m)

---

accuracy (m)

---

---

**Source of water**

- Tap
- Borehole
- Dam
- River
- Other

**Labour availability between 18 and 65**

- Yes
- No

**Access to irrigation scheme**

- Yes
- No

**general health of the household**

- Poor
- Average
- Good

**Ownership of farming equipment**

- Own
- Rent
- Borrow

**Source of energy**

- Electricity
- Solar
- Gas
- Firewood
- Paraffin
- Biogas

**Type of shelter**

- Brick-walled
- Mud-house
- Shacks
- Thatched-house

**Financial**

- Salaried job
- Remittances
- Grant
- Pension
- Option 5

**Have you noticed any changes in max/min temperature and rainfall**

- Yes
- No

**If yes, in what ways have you noticed the changes in temperature/ rainfall/**

- Decrease in monthly temperature
- Increase in monthly temperature
- No change in monthly temperature
- Decrease in minimum temperature
- Increase in minimum temperature
- No change in minimum temperature
- Decrease i

**Have you been affected by these climatic changes**

- Yes
- No

**If yes to the question above, In what way have you been affected (farm-activities)**

- Loss of crops
- Loss of Livestock
- Reduced forage
- Reduced crop yields
- Reduced forest resources
- Reduced milk yield
- Livestock health( heat stress/)
- Increased crop pests and diseases
- Reduced water availability (people & livestock)
- crops affected by frost
- Loss of income
- OTHERS

**If yes to the question above, In what way have you been affected (non-farm activities)**

- Loss of income
- Health
- Migrating to other areas
- Expenses to maintenance
- Reduced food availability
- Unable to travel to work
- Cultural activities
- Reduce labour availability
- OTHERS

**Have you experienced the following natural disasters**

- Floods
- Droughts
- Strong winds
- Hail
- Snow
- Lightning
- Rockfalls

**How have you been affected by these natural disasters**

Yes

No

**If Yes, please explain how you have been affected by natural disasters**

- Damage of roads
- Damage of bridges
- Damage of house property/ shelter
- Blasting of water pipes due to frost
- Damage of essential services (communication (network)/ electricity (powercut)/ water)
- Fires
- Death of people
- Higher maintenance costs due to damage
- Higher costs to provide warmth (electric/gas/solar heaters), firewood
- Erosion of agricultural land
- Destruction of crops
- Death of livestock
- Change in water quantity and quality
- OTHERS

**What adaptation methods have you tested**

- Crop diversification
- water harvesting/ water management strategies
- Conditional grants
- Selling livestock
- Borrowing money from friends/ relatives/ neighbors
- Migration
- Changing seed varieties (drought-resilient crops)
- Changing livestock breeds
- Change of diet/ alter food number of intake
- Assistance from the Government/ NGOs/ private sectors (IN WHAT WAYS)
- Informal organisations/assistance ( food sharing,
- Knowledge sharing,
- Cultural activities
- Income from selling natural resources (farm & forest products)
- Petty trade
- Soil management strategies
- Veld management
- Buy supplementary feeds
- Remittances
- Alter cropping calendar

If others, specify:

---

**Have the selected methods worked for you?**

- Yes
- No

If yes, please specify how

---

If No, then what else have you tried?

---

If No, what do you think is/ are the reason (s)?

*Appendix 5*

**Interview for veterinary officers in the Thabo Mofutsanyane District**

This interview is to assess the impacts of climate change on livestock farming in the Eastern Free State Region, South Africa. The information collected is based on the veterinary officers' perceptions of climate change. Coping measures and constraints in their implementation during the operation measures to manage climate change will be studied.

Date of interview.....

Name.....

Are farmers aware of how climate change would affect their livestock?

.....  
.....  
.....

Do changes in rainfall and temperature impact pasture and water availability in livestock farming?

.....  
.....  
.....

How do communities deal with the lack of livestock feed and water during low rainfall?

.....  
.....  
.....

Has there ever been a situation where the temperature was too high for livestock?

.....  
.....  
.....

Are diseases affecting livestock related to changes in climate? If yes, please explain.

.....

.....  
.....

What strategies have been employed by local communities to combat animal diseases?

.....  
.....  
.....

Does livestock mortality occur in this region due to heavy rains, severe weather events, and starvation?

.....  
.....  
.....

What reasons have been offered as a justification for not vaccinating livestock?

.....  
.....  
.....

Are these measures and interventions effective in addressing climate change issues?

.....  
.....  
.....

What education and knowledge dissemination programmes on climatic issues does the department undertake?

.....  
.....  
.....

