SMALLHOLDER FARMERS' PERCEPTIONS AND ADAPTATION TO CLIMATE CHANGE: A CASE OF UMKHANYAKUDE DISTRICT IN KWAZULU-NATAL PROVINCE OF SOUTH AFRICA

By

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DECLARATION

I declare that this thesis, hereby submitted for the degree of Doctor of Philosophy at the University of the Free State, is my own independent work, and has not been submitted for degree purposes to any other university. I hereby forfeit any copyright of this thesis to the University of the Free State.

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The following manuscripts form part of the research presented in this thesis.

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Manuscripts were conceived and conceptualised by Maziya, M. Maziya, M was also responsible for data collection and analysis. At the same time, Nkonki-Mandleni, B. and Van Niekerk, J. provided supervision and comments at every stage of producing the manuscripts.

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LIST OF ABBREVIATIONS AND ACRONYMS

DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
FAO	Food and Agriculture Organisation
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GHG	Greenhouse Gas
LM	Local Municipality
IDP	Integrated Development Plan
IIA	Independence of Irrelevant Alternative
IPCC	Intergovernmental Panel on Climate Change
KZN	KwaZulu-Natal
MNL	Multinomial Logit Regression
NCCA	National Climate Change Adaptation
NCCRP	National Climate Change Response Policy
NDP	National Development Plan
NGO	Non-Governmental Organisations
SDG	Sustainable Development Goals
SLF	Sustainable Livelihood Framework
SPSS	Statistical Package for Social Sciences
Stats SA	Statistics South Africa
TLUs	Tropical Livestock Units
VIF	Variance Inflation Factor
DFID	Department of International Development
UNDP	United Nations Development Programme

ABSTRACT

Climate change poses significant risks to smallholder farmers and affects global efforts to reduce poverty, ensure food security, and promote sustainable development. Due to their limited capacity to adapt and often residing in rural areas, smallholder farmers are susceptible to the adverse effects of climate change. The adaptation process involves two steps: farmers' perception of climate change and adopting appropriate adaptation strategies. The study's contribution lies in its policy implications, which aim to promote climate change adaptation in rural areas. The findings provide policymakers with valuable insights for designing effective interventions to improve rural livelihoods and enhance overall quality of life.

The main objective of this study was to investigate the perceptions and adaptation strategies of smallholder farmers on climate change in the uMkhanyakude district of KwaZulu-Natal province, South Africa. The specific objectives of the study were: (i) examine perceptions of smallholder farmers on climate change using information from smallholder farmers over a 20-year (1999-2019) production season; (ii) identify socioeconomic determinants of smallholder farmers' perceptions on climate change; (iii) determine the perceived impact of climate change on smallholder farmers' livelihoods; (iv) analyse the determinants of farmers' choice of adaptation strategies.

A survey was conducted among 400 smallholder farmers randomly selected using a stratified sampling procedure from the Jozini and uMhlabuyalingana local municipalities within the uMkhanyakude district. Farmers from various villages were randomly chosen. Farmers actively engaged in agricultural activities were invited to participate in the study. Quantitative data was collected using survey questionnaires, while qualitative data was gathered through focus groups and key informant interviews. STATA was employed for analysing quantitative data, while ATLAS.ti was used for qualitative data analysis.

Principal Component Analysis was applied to identify the dominant climate change perceptions in the uMkhanyakude district. The analysis revealed five primary themes of farmers' perceptions, namely: (i) natural disasters; (ii) institutional support; (iii) decreased crop yields and loss of assets; (iv) changes in temperature and rainfall; and (v) extension services on climate change and poor livestock production. A binary logistic regression model was used to analyse the socioeconomic factors influencing smallholder farmers' climate change perception. The results showed that age of the household head, education level, adult equivalents, membership in farmers' associations and access to irrigation played significant roles in shaping climate change perception.

The study employed the Sustainable Livelihood Framework to analyse the perceived impact of climate change on smallholder farmers' livelihoods. The findings indicated that drought, resulting from climate change, negatively impacted crop and livestock production in the district. Climate change also led to the depletion of forest resources, negatively affecting the income of local farming households. The Multinomial Logistic (MNL) regression model was employed to analyse the adaptation strategies adopted by farmers and the factors influencing their choices. The primary adaptation strategies were identified as mixed farming, irrigation, shifting planting dates, and cultivating drought-resistant crops. The MNL regression results highlighted that access to credit and extension services, female-headed households, market access, Tropical Livestock Units (TLUs), and land size influenced the adoption of climate change adaptation strategies. Access to credit emerged as the main driving force for adaptation across the identified strategies in the study area.

The empirical findings highlight the need for developing climate change communication mechanisms tailored to specific areas, considering the perceptions of smallholder farmers. The results indicate that membership in farmer organizations play an important role in shaping climate change perceptions. Therefore, when formulating communication strategies to disseminate climate change information, this channel should be considered.

The study revealed that smallholder farmers rely on various capital assets for their livelihoods, and climate change has negatively impacted their livelihoods. Considering this, it is recommended that extension services prioritise enhancing alternative livelihood strategies to diversify farm income. Access to rural finance is significant factor in facilitating the adoption of climate change adaptation strategies. Therefore, programmes supporting smallholder farmers should focus on facilitating their access to both formal and informal sources of credit.

Keywords: Climate Change, Perceptions, Adaptation, Livelihoods, PCA, MNL

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Climate change has emerged as a paramount societal concern, underscored by its significance and far-reaching implications for humanity (Farajzadeh, Ghorbanian & Tarazkar, 2022). Recent decades have borne witness to a discernible surge in natural disasters attributable to the shifts in climatic patterns, notably characterised by intensified occurrences of extreme meteorological events and unanticipated variations in temperature and precipitation (Farajzadeh *et al*., 2022). These occurrences have raised global awareness and collective commitment to addressing the threat posed by climate change (Ojo & Baiyegunhi, 2021). For example, global accords such as the Paris Agreement and the 21st Conference of the Parties (COP21), asserts the imperative to align greenhouse gas emission trajectories with the objective of limiting the rise in global temperatures below 1.5 ◦C or, in accordance with a broader tolerance, 2◦C above pre-industrial benchmarks is unequivocally affirmed (Fernandez and Daigneault, 2016). In addition, COP21 advocates for the widespread adoption of renewable energy sources and the facilitation of financial transfers from developed to developing nations, thereby expediting progress towards the articulated objectives (Fernandez & Daigneault, 2016). The steadfast commitment to these objectives was further underscored during COP26, a seminal event convened in Glasgow from 1-12 November 2021 (United Nations, 2018).

Most developing nations have grappled with severe climate-related threats that affect agricultural output due to their geographic location (IPCC, 2014). Most poor countries are located in the tropics and semi-arid zones and often contend with heightened temperatures and shortage of water resources (FAO, 2015). Although Africa’s greenhouse gas (GHG) emissions contribution to the atmosphere remains nominal, it experiences the most pronounced repercussions of climate change. Notably, the IPCC underscores the heightened vulnerability of sub-Saharan Africa, a region largely positioned across the warming tropics, emphasizing its constrained adaptive capacity to external pressures and changes (Leal Filho, Esilaba, Rao & Sridhar, 2015).

Climate change and variability are among the biggest threats to agricultural production for current and future generations. Scenarios on the vulnerability of world agriculture suggest that smallholder farmers in developing countries are the most affected by the negative effects of climate change because of their overreliance on a rainfed agricultural system and limited adaptive capacity due to poor resource endowments (Hitayezu, Zegeye & Ortmann, 2014; Jiri *et al*., 2015; Kassie *et al*., 2013).

Agriculture plays a crucial role in sustaining the livelihoods of many smallholder farmers in South Africa. There are over 240 000 market-oriented smallholder farmers and an estimated two to four million subsistence-oriented farmers (Ncube & Fanadzo, 2017). Most of these farmers reside in communal areas where agriculture is a dominant activity (Maziya, Mudhara & Chitja, 2017). Smallholder farmers in South Africa face challenges related to limited livelihood assets and high vulnerability to food insecurity (Thamaga-Chitja & Morojele, 2014). According to Statistics South Africa's 2016 community survey, approximately 23% of smallholder farmers, primarily engaged in grain crops, vegetable production, poultry farming, and livestock rearing, are in KwaZulu-Natal (KZN) province (Stats SA, 2016).

The Food and Agriculture Organisation (FAO, 2016) argued that smallholder farming systems must more than double their agricultural output to sustain the growing world population. The impact of climate change, characterised by irreversible shifts in weather patterns, poses a significant threat to agricultural productivity, particularly in developing countries (Hitayezu, 2015). In these contexts, farmers' vulnerability, and susceptibility to the negative impacts of climate change are compounded by various social, environmental, and economic factors (Elum, Modise & Marr, 2017).

Climate change vulnerability refers to the extent to which a system is prone to and unable to cope with the adverse impacts of climate change (Laitonjam, Singh & Feroze, 2018). Rural households heavily rely on climate-sensitive natural resources like land and water (Jiri *et al*., 2015). In addition, rural households engage in climate-sensitive activities such as animal husbandry, rain-fed agriculture, collecting forest wood for fuel, and gathering wild herbs for dietary supplementation (Jiri *et al*., 2015). Consequently, climate change exacerbates the challenges faced by rural households by diminishing the availability of these natural resources. In contrast to the observed global average temperature increase of 0.65°C, South Africa has experienced a temperature rise that is 1.5 times higher (Ziervogel *et al*., 2014). Climate change in the country is characterised by extreme drought and heavy rainfall events, particularly in the eastern region (DEA, 2013). General Circulation Models (GCMs) predict further temperature increases of 2.9-3.9°C and 3.9-9.6°C by 2050 and 2100, respectively (Ziervogel *et al*., 2014). In addition, rainfall is expected to decrease by 2-8% and -8% by 2050 and 2100, respectively (Ziervogel *et al*., 2014).

Climate change directly impacts agriculture by altering the suitability of certain regions for crop cultivation. It also indirectly affects agricultural production by increasing land degradation risk (Hitayezu, 2015). For instance, in the KZN province of South Africa, an agro-ecological zoning study indicated that rising temperatures are likely to shorten the maize growth cycle (Estes *et al.,* 2013). According to estimates from the Intergovernmental Panel on Climate Change (IPCC) in 2014, climate change is projected to reduce average agricultural yields by 1%, while an annual increase of 14% in yield productivity is necessary to meet the food demands of a growing population (IPCC, 2014). Although higher temperatures can initially benefit crop growth, yields tend to decline if daytime temperatures exceed specific thresholds for different crops (FAO, 2016). Climate change exacerbates the challenges agricultural systems face in developing countries, particularly due to the absence of effective adaptation interventions, resulting in decreased agricultural productivity (Pereira, 2017).

Enhancing agricultural productivity entails reducing farmers' vulnerability to different stressors that can negatively impact their livelihoods. Smallholder farmers often need to adopt on-farm adaptation measures to mitigate these challenges. Climate change adaptation involves a two-step process. The initial step involves farmers recognising and perceiving changes in the climate, while the subsequent step necessitates taking proactive measures to address the adverse impacts of climate change. Perception, therefore, plays a crucial role as a prerequisite for climate change adaptation.

In regions of South Africa with a significant number of dryland farmers, there is a notable lack of awareness regarding climate change (Hitayezu, Wale & Ortmann, 2017). For instance, in the Eastern Cape province, only 48% of farmers were aware of climate change in 2014 (Muller & Shackleton, 2014). The current body of empirical literature suggests that this lack of awareness is primarily attributed to the complex nature of biophysical processes, making it difficult for smallholder farmers to discern and understand the intricacies of climate change (Gandure, Walker & Botha, 2013; Muller & Shackleton, 2014).

According to the IPCC's 2013 fifth assessment report (AR5), positive climate change perception should lead to two crucial behavioural responses (IPCC, 2013). Firstly, governments can address climate change by reducing farmers' exposure to current variability. This can be achieved through various measures to mitigate climate change impacts. Secondly, governments can take proactive steps by integrating adaptation and mitigation strategies into decision-making processes at all levels. By doing so, agricultural production can be safeguarded, particularly in developing countries where rainfed systems have been adversely affected by unpredictable climate patterns and extreme weather events, significantly impacting smallholder’s farmers' livelihoods (Mubiru *et al*., 2018). It is, therefore, essential to comprehend the behaviour of farmers before formulating policies that enhance the adaptive capacity of farming communities (Vermeulen *et al*., 2012).

Adaptation to climate change and variability is essential for farming communities. Bhaktikul (2012) suggests that societies must acquire knowledge about climate risk, evaluate adaptation options, mobilise resources and create favourable conditions to enable successful climate change adaptation. While climate change may be viewed as a new phenomenon, the literature on climate change suggests that African and communities around the world have always adapted to various environmental and socioeconomic stresses (Phophi, Mafongoya & Lottering, 2020; Mulwa *et al*., 2017). For instance, societies in arid regions have traditionally adapted to drought. Considering the projected intensification of extreme weather patterns in the foreseeable future, societies must draw from past experiences and apply accumulated knowledge in future adaptation efforts (Taylor & Peter, 2014).

A combination of environmental, cognitive, and socioeconomic factors influences climate-driven adaptation. According to neoclassical economists, farmers with limited access to climate change information typically respond to regular climatic variability by making tactical adjustments to variable inputs (Hitayezu, 2015). However, when long-term agricultural production or profitability fluctuations raise public awareness of climate change, autonomous learning and adaptation processes are triggered (Saleh-Safi, Smith & Liu, 2012). Over time, farmers consider modifying fixed inputs such as land as they gain access to climate change information from both internal and external sources (Opiyo *et al*., 2015). The judgments and decision-making of farmers regarding climate change are further influenced by institutional, cultural, and socio-psychological factors (van der Linden, 2015).

1.2. THE RESEARCH PROBLEM

Studies indicate that Africa’s smallholder farmers are negatively affected by climate change, mainly due to their reliance on rain-fed farming (Jiri *et al*., 2015; Kassie *et al*., 2013). The challenges of climate change have profound implications for agricultural development and human well-being. Climate change shocks and stressors disproportionately affect individuals who are already vulnerable due to poverty and limited institutional support, leading to severe negative consequences for food security and livelihoods (Connolly-Boutin & Smit, 2016). Smallholder farmers, lacking the necessary resources to effectively adapt to and mitigate the adverse effects of climate change, bear the brunt of these pressures (Chivenge *et al*., 2015). The perception and adaptation of farmers to negative impacts of climate change are critical for safeguarding their livelihoods and ensuring food security.

The agricultural sector in KZN faces multiple challenges, including a higher population density, a more significant proportion of smallholder farmers, reliance on rain-fed agriculture, and significant land degradation. Climate change projections for the province indicate increasing temperatures, more frequent extreme weather events, and potential changes in rainfall patterns. The high levels of poverty (60.7%) and inequality within the province contribute to the heightened vulnerability of its population to climate change and variability (Wilk, Andersson & Warburton, 2013; Stats SA, 2018). KZN has the highest human vulnerability to climate risks in the country, combined with the third lowest adaptive capacity (Hitayezu *et al*., 2014; Wilk *et al*., 2013). Factors such as deteriorating social networks due to HIV/AIDS, limited access to resources, and governance challenges further exacerbate the vulnerability of smallholder farmers to climate change (Connolly-Boutin & Smit, 2016).

Adaptation to climate change is often viewed as a context-specific phenomenon, underscoring the importance of local-level analyses to better understand the underlying adaptation processes and enable more targeted adaptation policies by national and local governments, NGOs, and bilateral donors.

In South Africa, there are a plethora of studies that have been conducted to assess farmers' vulnerability to climate change (i.e., Theron, Midgley, Hochrainer-Stigler, Archer & Tramberand, 2023; Okolie, Danso-Abbeam & Ogundeli, 2023). However, these studies cannot be generalized to include the uMkhanyakude district due to two main reasons. Firstly, farmers' livelihoods tend to differ across regions because of the ecological orientation of the regions. Secondly, regional climatic variations mean that the impact of climate change would be experienced differently across areas in the same region. The differences in climatic variations in the same region show the need for local studies on the perception and impact of climate change on the livelihoods of farmers. An understanding of the adverse effects of climate change on the livelihoods of rural people is crucial in the design of appropriate climate change policies.

1.3. OVERALL OBJECTIVE OF THE STUDY

The study's main objective was to assess smallholder farmers' perceptions of climate change and adaptation strategies adopted by farmers in the uMkhanyakude district of KwaZulu-Natal, South Africa.

1.3.1. Sub-Objectives

The specific objectives of the study are to:

i. Examine perceptions of smallholder farmers on climate change using information from smallholder farmers over a 20-year (1999-2019) production season.
ii. Identify socioeconomic determinants of smallholder farmers' perceptions of climate change.
iii. Determine the perceived impact of climate change on smallholder farmers' livelihoods.
iv. Analyse the determinants of farmers' choice of climate change adaptation strategies.

1.3.2. Research Questions

The following research questions address the problem:

i. What are smallholder farmers' perceptions of climate change over the 20-year (1999-2019) production period?
ii. What are the socioeconomic determinants of smallholder farmers' perceptions of climate change?
iii. What are the smallholder farmers' perceived impacts of climate change on livelihoods?
iv. What are the determinants of farmers' choice of adaptation strategies?

1.3.3. General Hypothesis for the Study

Smallholder farmers perceive climate change and have adopted adaptation strategies to counter the negative effects of climate change.

1.4. THEORETICAL GROUNDING

The relationship between climate change and smallholder farming outcomes can be examined through various theoretical frameworks. In this study, the Theory of Planned Behaviour (TPB) is the foundation, as depicted in Figure 1.1. TPB consists of three key components: behavioural beliefs (attitudes towards behaviour), normative beliefs (subjective norms), and control beliefs (behavioural control).

The TPB is a psychological theory that proposes that behavioural intentions, such as climate change adaptation, are influenced by individuals' beliefs and attitudes towards the behaviour, subjective norms, and perceived behavioural control (Niles & Mueller, 2016). By identifying the underlying determinants of behaviour, the TPB aims to predict and comprehend behaviours related to climate change, including perception and adaptation. In addition, some scholars have underscored the significance of self-identity in comprehending the motivations behind farmers' adoption of specific practices. Self-identity pertains to the degree to which a behaviour is perceived as an integral part of an individual's identity, linked to the social group to which the farmer belongs. It mirrors the farmers' personal value system, worldview, experiences, and moral principles, acting as an internal compass that influences their perceptions of external factors and preferences.

The TPB has broad applicability as a conceptual framework in studying human action. It has been successfully applied in various domains, such as food consumption and health behaviour (Ajzen, 2015). However, its application to climate change adaptation remains limited, with only a few studies applying the theory in this context of climate change (Lin, 2013; Jellason *et al*., 2019; Mills *et al*., 2017).

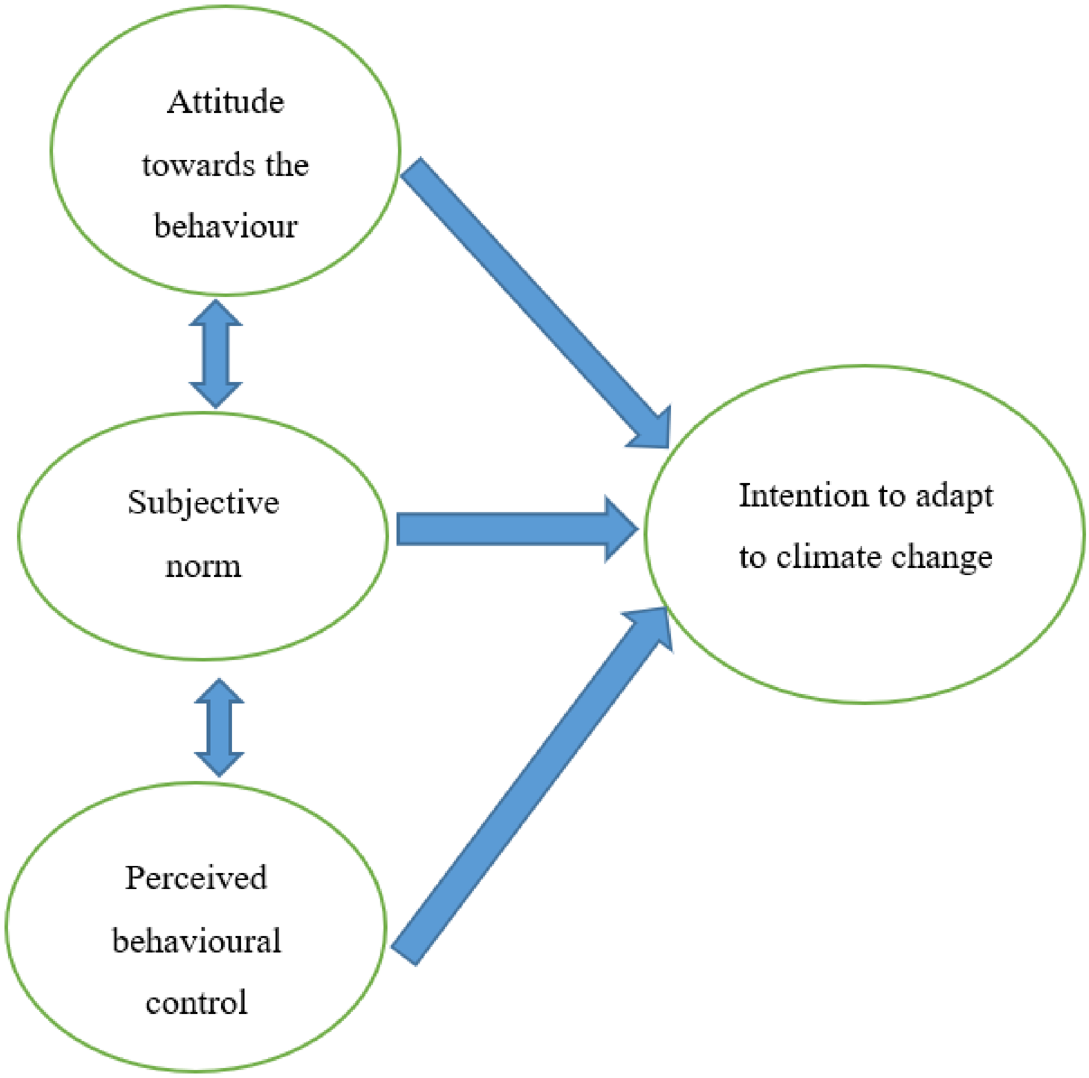

Figure 1.1: The Theory of Planned Behaviour

Source: Adapted from Ajzen (1991)

1.5. SIGNIFICANCE OF THE STUDY

Farmers are expected to be responsive to the ongoing environmental changes although they do not have the potential to perform all the adaptive land use management tasks autonomously. Bhatasara and Nyamwanza (2018) observed that another important dimension of the adaptation discourse is that the rural poor are often excluded from policy-making processes. As a result, policies formulated at the central government level are not sufficiently responsive to the policy needs of citizens at the local level and, therefore, not conducive to local livelihood and adaptation strategies.

South Africa ratified the United Nations Framework Convention of Climate Change (UNFCCC) and entered into acceptance of the Kyoto protocol in 2002. Through the national climate change response white paper, the government has made strong commitments to integrate climate change mitigation and adaptation into national development policies (Republic of South Africa, 2011). Amongst the strategic priorities, the policy paper recognizes the need for developing education and training programmes to facilitate access to climate information through agricultural extension and promote understanding and informed participation in the fight against climate change at all levels. The evidence-based information on the understanding of climate change among smallholder farmers and the constraints they face in acquiring appropriate knowledge are two crucial ingredients for the design of effective climate change communication strategies. This study is expected to help establish facts indicating climate change perception and the factors that affect farmers' choice of adaptation methods for climate change and the barriers to adaptation.

Scientific publications emanating from this study are expected to serve as vital instruments to initiate academic discourse among researchers. Although the study will focus on KwaZulu-Natal, the results of this study are expected to be relevant and helpful to many parts of South Africa and sub-Saharan Africa with similar climatic and socio-economic settings. Essentially, the research is important because an understanding of the trend of current climate change, its impacts on livelihoods, current response strategies and identification of vulnerabilities and stressors help to predict the likely future changes, impacts, coping strategies and social vulnerability. Furthermore, the study is expected to provide input to efforts to formulate policy, programmes and activities that could accelerate adaptation strategies at household and community level. This research is also expected to serve as a baseline study for further studies especially about community perception on climate change impacts and response strategies in the uMkhanyakude district of KZN. In explicit terms, examining the current influence of climate change impacts and internal and external responses and predicting future adaptive capacity and constraints of communities lays a good foundation to map the communities' ability to cope with climate change and to enhance the viability of internal and external agency development interventions.

1.6. ORGANISATION OF THE THESIS

This thesis is structured into eight chapters, each serving a specific purpose. Chapter 1 introduces the research problem and provides the study's background and objectives. In Chapter 2, a comprehensive literature review is presented, covering topics such as farmers' perceptions of climate change, the impact of climate change on rural livelihoods, climate change adaptation measures, and South Africa's response to climate change. Chapter 3 outlines the research methodology, including details of the study area, data collection methods, data analysis techniques, and ethical considerations. Chapters 4 to 7 form the empirical core of the thesis. Chapter 4 examines smallholder farmers' perceptions over a 20-year production period (1999-2019), utilising Principal Component Analysis (PCA) to categorise their perceptions of climate change. Chapter 5 employs the binary logit regression model to analyse the determinants of climate change perception among farmers. In chapter 6, the perceived impacts of climate change on smallholder farmers' livelihoods are investigated using the Sustainable Livelihood Framework. Chapter 7 focuses on analysing climate change adaptation methods adopted by farmers and their influencing factors. Finally, Chapter 8 concludes the thesis by summarising the study's main findings, presenting policy recommendations based on the research outcomes, and highlighting potential areas for further research exploration.

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

This chapter provides a comprehensive literature review on the perceptions and adaptation of smallholder farmers to climate change. It begins by presenting a global perspective on climate change, specifically emphasising the negative impacts experienced in Africa. The chapter then delves into the characteristics of smallholder farmers in South Africa. It examines how climate change has adversely affected smallholder farming and the livelihoods of rural communities. The review highlights the challenges smallholder farmers face, including limited resources and low adaptive capacity, in coping with climate change and variability.

Furthermore, this chapter explores smallholder farmers' perceptions regarding climate change adaptation and the barriers they encounter in implementing adaptive measures. It also explores the socio-psychological factors influencing farmers' perceptions of climate change. In addition, the chapter discusses aspects of behavioural decision-making in the context of climate change adaptation. The final section of this chapter focuses on macro-level responses to climate change, exploring the broader strategies and policies implemented to address the challenges posed by climate change at a larger scale.

2.2. CLIMATE CHANGE IN THE GLOBAL CONTEXT

The definition of climate change is a subject of debate among scholars, leading to various interpretations. One prominent organisation engaged in climate change research and policy guidance is the Intergovernmental Panel on Climate Change (IPCC). The IPCC defines climate change as the long-term alteration of weather patterns, typically spanning decades or more (IPCC, 2018). This change can be attributed to internal variability within the climate system and external influences, which are determined through statistical analysis (IPCC, 2018a). Human activities have contributed to the acceleration of climate change, particularly since the industrial revolution (IPCC, 2013; Richards, Wollenberg & Buglion-Gluck, 2015; Fellmann *et al*., 2017).

According to the empirical evidence presented in the Fifth Assessment Report of the IPCC (IPCC, 2014), the Earth’s climate is undergoing significant and unprecedented changes, surpassing any observed variations in the past 400 000 years. The past seven decades have been particularly notable, as they have been recorded as the hottest in the past millennium, accompanied by shifts in precipitation patterns that have led to more frequent and severe extreme weather events like droughts and floods (IPCC, 2014). Furthermore, there has been an increase in warm days since the 1950s, and future projections suggest that heatwaves will become more frequent and intense (Kim, Choi & Min, 2022). Consequently, these temperature rises, and alterations in rainfall patterns affect water availability and cropping patterns.

Scientific evidence indicates that the accumulation of greenhouse gases (GHGs) such as methane, carbon dioxide, and nitrous oxide has led to global warming. It is reported that human activities, including deforestation, housing development, mining, and road construction, have significantly contributed to the increase in anthropogenic greenhouse gas concentrations since the mid-twentieth century (Lemma, 2016). These human-driven activities disrupt the natural balance of the atmosphere and the Earth's ecosystems, reducing the natural capacity to remove greenhouse gases from circulation (Ugwuoke, 2013). The resulting increase in atmospheric heat leads to the greenhouse effect, causing changes in the atmosphere's composition (Lemma, 2016). Climate models are widely utilised to project future climate scenarios (IPCC, 2013). These models compare simulations with observed global temperature increases over the past century to understand the role of greenhouse gas emissions from human activities (IPCC, 2013). The findings from these simulations demonstrate that the observed temperature patterns can be attributed to the inclusion of human-induced greenhouse gases in the climate models (IPCC, 2013).

According to predictions by the IPCC, global average temperatures are expected to rise between 2°C and 4.5°C by the year 2100, indicating a doubling of carbon dioxide concentrations in the atmosphere (IPCC, 2014). Over the past 50 to 100 years, the African continent has experienced a temperature increase of 0.5°C (IPCC, 2014). Studies specific to Africa project temperature increases ranging from 3°C to 4°C by the end of the 21st century, 1.5 times higher than the predicted global average (Bryan *et al.*, 2013; IPCC, 2014; IPCC, 2018).

Rising temperatures are expected to profoundly impact precipitation patterns and atmospheric moisture. The increase in atmospheric temperature leads to greater evaporation and water vapour, resulting in increased precipitation, more intense storms, and rising sea levels. Projections indicate that Southern Africa is likely to experience a decline in average rainfall, while central and Eastern Africa may see increased precipitation during the 21st century (Nicholson, Funk & Fink, 2018).

Visible signs of climate change impacts are already observed on the African continent. For instance, the glaciers and snowcaps on Mount Kilimanjaro have been shrinking since 1912

(Lemma, 2016). If the current trend continues, most of the ice on Mount Kilimanjaro's glaciers will disappear within the next decade (Lemma, 2016). In addition, over the past 45 years, ocean temperatures have increased by 0.31°C in the upper 300 metres and 0.06°C to a depth of 3000 metres (Rhein *et al*., 2013). According to the IPCC, with global warming of 1.5°C by 2100, global average sea levels could rise by 0.1 metres (IPCC, 2018).

Agriculture plays a dual role in global climate change, serving both as a contributor to greenhouse gas (GHG) emissions and as a sector vulnerable to its impacts (Ugwuoke, 2013). Approximately 10 to 12% of the total annual global emissions can be attributed to GHG emissions from agricultural activities (IPCC, 2014). Livestock and crop production are significant methane and nitrous oxide sources, two potent greenhouse gases (FAO, 2016). These emissions arise from various agricultural practices such as fertilisation, cultivation, livestock rearing, and manure management (Fellmann *et al*., 2017). Methane is produced during ruminant digestion and can be released from stored manure and organic waste (Fellmann *et al*., 2017). Nitrous oxide emissions result indirectly from using organic and inorganic fertilisers in croplands. Agricultural GHG emissions contribute around 35% of national emissions in developing nations and approximately 12% in developed countries (Richards *et al*., 2015).

According to FAO (2016), climate change has detrimental effects on agricultural productivity, leading to a decline that adversely impacts global food prices. Climate change-related disasters, such as floods and droughts, worsen global food shortages, increasing food prices that negatively affect millions of low-income individuals in developing countries. These food price increases are projected to exacerbate poverty and hunger, posing challenges to achieving the Sustainable Development Goal of eradicating poverty and hunger by 2030 (FAO, 2016). The most vulnerable to these impacts are smallholder producers in developing countries, who heavily rely on agriculture for their subsistence and income.

Developed and developing countries exhibit significant disparities in greenhouse gas emissions and the severity of climate change impacts. Despite being responsible for a smaller share of emissions, developing nations often experience more pronounced adverse effects of climate change (Levy & Patz, 2015). Developed countries possess greater financial resources and are more resilient in recovering from extreme weather events. In contrast, developing countries may require foreign assistance and face more extended recovery periods following climate-related disasters. In a study by Diffenbaugh and Burke (2019), global climate models were utilised to estimate the influence of global warming on global inequality. Their findings indicate that global warming has decreased economic growth in low-latitude countries while high-latitude countries have experienced increased economic growth. For instance, warming brings the mean temperature of colder countries like Norway closer to their optimal range, resulting in incremental economic benefits. Conversely, warming pushes the mean temperature of warmer countries like India further away from their temperature optimum, leading to cumulative losses.

2.3. CLIMATE CHANGE IN SOUTH AFRICA

The African continent is particularly vulnerable to the severe negative impacts of climate change due to its high exposure and limited adaptive capacity (Gbetibouo, Hassan & Ringler, 2010). In the case of South Africa, the country's heavy reliance on rainfed agriculture, coupled with inadequate technical and institutional capacity, further amplifies its vulnerability to climate change and variability (Schilling *et al*., 2020). The agricultural sector plays an important role in the country and contributes to 5% of South Africa's gross domestic product (GDP) and provides employment to nearly 6% of the total labour force (South Africa Yearbook, 2021).

Projections indicate that temperatures in the interior region of South Africa are expected to increase by 5 to 8°C (Mbokodo, Bopape, Chikoore, Engelbrecht & Nethengwe, 2020). At the same time, the eastern part of the country will experience wetter conditions, and the western and southern regions will become drier (DEA, 2013). Consequently, drier conditions are anticipated during the winter in the southwestern parts of the country, potentially leading to a shortened winter rainfall period. On the other hand, rainfall is expected to increase during the summer months in the northern and eastern regions, with the possibility of excessive rain and flooding.

South Africa is characterised by arid conditions and a low rainfall index and receives an annual mean precipitation of less than 500 mm (Elum et al., 2017). The country boasts the largest surface area under irrigation in the Southern African region, with 1.3 million hectares dedicated to irrigation (Elum et al., 2017). Climate change impacts in South Africa primarily manifest through droughts and floods. These climate-related disasters, as Elum et al. (2017) reported, have resulted in infrastructure damage and, unfortunately, sometimes, loss of life. Table 2.1 presents a compilation of climate change-related events that have caused significant havoc in South Africa over the past two decades. These natural disasters have significantly impacted various regions of South Africa, affecting communities, infrastructure, and the environment.

These disasters highlight the country's vulnerability to a range of climate-related events and the importance of implementing effective disaster preparedness and response measures to minimise their adverse effects.

Table 2.1: Climate Disasters in the Past 20 Years in South Africa

Year	**Natural disaster**
2003	Drought in the Western Cape
2010-2011	Floods in settlements along the orange river
2012	Floods in the Eastern Cape, Tornado in the Free State, heavy storm in Cape Town
2013	Floods in Johannesburg, Wildfire in pearl, Storm in the Free State
2014	Orkney earthquake
2015-2016	El Nino-induced drought in South Africa
2021	Cyclones in parts of Mpumalanga, Limpopo and KwaZulu-Natal

Source: Disaster Report (2015)

South Africa is highly susceptible to the impacts of the El Nino Southern Oscillation (ENSO), which often leads to severe droughts (Baudoin *et al*., 2017). Historical records indicate that South Africa experienced significant droughts from 1982-1984, 1991-1992, and 1994-1995 (Baudoin *et al*., 2017). Among these, the drought in 1991-1992 stands out as the most severe on record and the entire Southern African region faced the threat of famine, with 30 million people urgently needing food assistance (Baudoin *et al*., 2017).

In more recent years, South Africa encountered another severe El Nino-induced drought between 2014 and 2016, leading to water restrictions in major cities like Johannesburg and Cape Town (Enqvist & Ziervogel, 2019). The drought negatively impacted crop yields in 2016, affecting neighbouring countries such as Zimbabwe, Eswatini, and Lesotho, which heavily rely on imports of grains from South Africa (AgriSA, 2016). The consequences of this drought were far-reaching, causing devastating effects on the country’s agricultural and economic systems, including increased unemployment and negative repercussions on downstream industries (AgriSA, 2016).

2.4. CHARACTERISTICS OF THE SOUTH AFRICAN AGRICULTURAL SYSTEM

The South African National Development Plan (NDP) envisions smallholder agriculture as a promising avenue for creating sustainable livelihoods and alleviating rural poverty by 2030 (National Planning Commission, 2012). Recognising this potential, the South African government has set specific targets to increase the number of smallholder farmers selling their produce. The initial goal was to raise the number from 200 000 to 250 000 by 2014 and subsequently to 500 000 smallholders by 2020 (Aliber & Hall, 2012). However, it is not clear whether the government has succeeded in this endeavour. Smallholder farmers are predominantly located in former homeland areas and primarily consist of black farmers, reflecting the dualistic nature of South African agriculture (Louw, Davids & Scheltema, 2017; Zantsi, Greyling & Vink, 2018). This dualism is widely attributed to the historical racial apartheid policies (Sinyolo, 2016).

Smallholder farmers occupy marginal areas within the former homelands and utilise approximately 13% of South Africa's agricultural land (Pienaar *et al*., 2015). In contrast, the commercial agricultural sector, dominated by around 35 000 white farmers, occupies 87% of the agricultural land and accounts for 95% of the total agricultural output (Pienaar *et al*., 2015). Different terms such as peasant farmers, food security farmers, smallholder farmers, and resource-poor farmers are used to describe smallholder farmers in South Africa (Aliber & Hart, 2009). In addition, the smallholder farming sector is characterised by small-scale farms, limited use of inputs and machinery, reliance on traditional production methods and a lack of institutional capacity and support (Pienaar & Traub, 2015).

Smallholder farming plays a crucial role in the livelihoods of rural communities in South Africa. These farmers typically raise livestock and cultivate crops for sale and household consumption. According to Statistics South Africa (Stats SA, 2016), the country has approximately 2.4 million agricultural households, with the highest concentration (23%) found in the KwaZulu-Natal province of South Africa. Many smallholder farmers engage in agriculture to secure an additional source of food for their households (Stats SA, 2016).

To support and enhance the productivity and sustainability of the smallholder farming sector, the South African government, specifically the Department of Agriculture, Land Reform and Rural Development (DALRRD), has implemented national programmes such as the mechanisation programme and the Comprehensive Agricultural Support Programme (CASP). These initiatives aim to provide assistance and resources to smallholder farmers. However, the success of these government interventions relies on the farmers' positive response and participation in these policy initiatives (Sinyolo, 2016). Smallholder farmers are particularly vulnerable to the adverse effects of climate change, which can further exacerbate their challenges. The following section will explore climate change's impact on smallholder farmers' livelihoods.

2.5. IMPACT OF CLIMATE CHANGE ON THE LIVELIHOODS OF SMALLHOLDER FARMERS

The concept of "livelihoods" has gained significant prominence in development discourse, particularly in understanding the activities undertaken by rural populations to sustain their lives (Maziya, 2013). Amartya Sen is often credited with shifting the focus of food security from mere food availability to the importance of households' access to capital assets (Burchi & Muro, 2016). The Sustainable Livelihood Framework highlights that households require various assets to pursue livelihood strategies (Scoones, 1998). These assets encompass human, natural, financial, social, and physical dimensions.

Smallholder farmers, for instance, rely on natural capital, such as the environment, to cultivate crops. They utilise financial capital (i.e. cash, remittances) to support their farming operations, employ human capital through labour and expertise, harness social capital to exchange farming knowledge and leverage political capital to influence agricultural policies and government programmes. Farmers can sustain their livelihoods and respond to challenges by effectively using these assets without compromising their resilience to shocks (Maziya, 2013). However, the negative impacts of climate change pose a significant threat to the natural assets that underpin agricultural activities (IPCC, 2014). As climate change intensifies, the availability and quality of natural resources vital for farming may be eroded, posing challenges to the sustainability of smallholder livelihoods.

Scholars widely agree on the significant threat posed by climate change and variability to planet Earth (Jiri *et al.*, 2015; IPCC, 2018). The detrimental effects of climate change and variability are particularly pronounced for the 2.5 billion individuals worldwide who rely directly on agriculture for their livelihoods (Ali & Erenstein, 2017). Among the rural poor, especially in sub-Saharan Africa, agriculture plays a crucial role, predominantly through rainfed and subsistence farming systems. It is supplemented by ecosystem services like wild fruits and plants, contributing to food security (Nhemachena *et al.*, 2014). The impacts of climate change directly affect the natural environment essential for agricultural productivity (FAO, 2016). These challenges arise alongside a growing global demand for food, fuel, and other fundamental human necessities. In South Africa, the effects of global warming are manifested in temperature fluctuations and changes in rainfall patterns (Hitayezu *et al.*, 2014). Consequently, smallholder farmers in South Africa have had to adapt their farming practices by adjusting planting dates and adopting new crop varieties.

Climate change significantly impacts the livelihoods of a large proportion, around 70-80% of smallholder farmers in Africa, as their ability to adapt is limited (IPCC, 2014; AGRA, 2017). In addition, women in developing countries, who constitute the majority of the agricultural labour force, bear a disproportionate burden of poverty resulting from adverse environmental effects (Elum, 2017). Projections from the IPCC using climate models indicate that by 2100, agricultural losses in most parts of the Sahara could range from 2% to 7% of GDP (IPCC, 2018). In western and central Africa, agricultural losses due to climate change are expected to range from 2% to 4% of GDP, while in southern Africa, these losses are projected to increase from 0.4% to 1.3% of GDP by 2100 (IPCC, 2018). Agricultural productivity needs to increase by approximately 14% per decade to meet the rising food demand driven by population growth (IPCC, 2014).

Maize, wheat, and rice are essential staple crops for many people, particularly in developing countries. These crops contribute around 30% of food calories consumed by approximately 4.5 billion individuals (Gautam, Shrestha & Subedi, 2021). Smallholder farmers in Latin America, Africa, and Asia predominantly cultivate them under rainfed conditions (United Nations, 2015). Projections indicate that global maize production could decline by 3% to 10% by 2050, while wheat production in developing countries may decrease by 29% to 34% during the same period (Waqas, Wang, Zafar, Noor, Hussain, Nawaz & Farooq, 2021). Fluctuations in the productivity of these staple crops, driven by climate change and variability, can lead to price fluctuations that negatively impact smallholder farmers and consumers in developing nations.

Climate change and variability broadly impact the four pillars of food and nutrition security: availability, access, utilisation, and stability. Food security ensures that "all people at all times have physical and economic access to adequate, safe, and nutritious food to meet their daily requirements for an active and healthy life" (FAO, 2006). Sub-Saharan countries already face food and nutrition security challenges due to factors such as poverty, high unemployment rates, inadequate infrastructure, and low levels of physical and human capital (International Monetary Fund, 2022). The negative consequences of climate change, such as severe droughts, directly affect crop productivity, leading to reduced food availability. Climate-related disasters like floods erode the natural assets many smallholder farmers rely on for their livelihoods, resulting in reduced household incomes and diminished purchasing power. This, in turn, affects access to food. FAO (2016) highlights that extreme weather events can disrupt the stability of food availability, access, and utilisation through changes in seasonality, variability in ecosystem efficiency, increased supply risks, and decreased supply predictability.

Changes in climate conditions, including shifts in temperature and rainfall patterns, alter the length of the growing season and pose challenges for smallholder farmers, often forcing them out of production (Shisanya, 2015). Projected temperature increases in the African region will negatively impact farmers' ability to control pests and diseases (Nguru & Mwongera, 2023). Higher temperatures can accelerate the life cycles of insects, such as aphids, moths, and butterflies, leading to increased pest populations (Cornelissen, 2011). Warmer conditions also facilitate greater breeding of pests, resulting in wider pest distribution. This intensification of pest pressure leads to crop damage, reduced farm revenues, and increased vulnerability for smallholder farmers (Phophi *et al*., 2020). Given the significance of subsistence-oriented crop production for rural livelihoods, the proliferation and distribution of pests can further jeopardise the household food security of smallholder farmers, who are already affected by recurrent drought and other livelihood shocks.

The negative effects of climate change, including increased temperatures and rainfall variations, harm livestock production (Rojas-Downing *et al.*, 2017). Future projections indicate that these factors will lead to changes in water availability, animal production and reproduction, livestock feed quality and quantity, and an increase in pests and animal diseases (Rojas-Downing *et al*., 2017). These climate-induced declines in livestock production are likely to affect approximately 1 billion smallholder farmers worldwide who rely on livestock for their livelihoods (Hatab, Cayinato & Lagerkvist, 2019).

In South Africa, climate change and variability have been particularly felt in rural provinces such as KZN and the Eastern Cape (Gbetibouo *et al*., 2010). The combination of climate change impacts and challenges such as land degradation and over-reliance on rain-fed agriculture has compounded the difficulties smallholder farmers face in these regions (Hitayezu *et al*., 2014). Barriers to effective adaptation include low literacy rates, limited access to irrigation infrastructure, and high HIV rates (Hitayezu *et al*., 2014).

Sietz, Choque and Ludeke (2013) argued that weather extremes frequently threaten the livelihoods of smallholder farmers. South Africa has experienced severe weather events leading to livestock deaths, crop damage, and property loss (Elum *et al*., 2017). Floods and droughts are the most common climate disasters in the country. Floods, often caused by deforestation and land degradation, have increased in incidence (Rogger *et al*., 2017). Between 2014 and 2016, Southern Africa experienced a severe drought resulting in reduced rainfall and inhibited crop production (FAO, 2016). Future El Nino episodes are expected to compromise further food and nutrition security, economic growth efforts, and poverty reduction initiatives (Nath & Bhagirath, 2011; Simatele, Tony & Munacinga, 2012).

2.6. SMALLHOLDER FARMERS' PERCEPTIONS OF CLIMATE CHANGE

Understanding farmers' perceptions of climate change is crucial for effectively implementing programmes to mitigate its negative effects on smallholder farmers (Lemma, 2016). Individual and community behaviours are influenced by how they perceive problems (Mills *et al.*, 2017). Climate risk perception is linked to beliefs about the adverse consequences of valued objects and is influenced by individuals' values and worldviews (Arbuckle, Morton & Hobbs, 2015). Climate risk perception can vary between countries and even among individuals within the same community and country (Whitmarsh, 2011; Smith & Leiserowitz, 2012). Therefore, when studying perception and adaptation to climate change, socioeconomic factors should be considered.

Traditional agricultural impact assessment studies have often relied on standard simulation approaches that assume an accurate detection of climate change (Deressa, Hassan & Ringler, 2011). Economic models, on the other hand, recognise the importance of climate change perception as a prerequisite for adaptation (Deressa *et al*., 2011). Adaptation to climate change is seen as a two-step process. The first step involves smallholder farmers perceiving that climate change is occurring, while the second step requires them to take decisive action by adopting and implementing adaptation strategies (Deressa *et al*., 2011). Indeed, several studies have demonstrated that farmers' perception of climate change plays a crucial role in their willingness to adopt and implement adaptation measures (Spence *et al*., 2011; Spence, Poortinga & Pidgeon, 2012; Hyland *et al*., 2015).

Research that employs environmental behaviour theories has consistently demonstrated a connection between people's beliefs, awareness of environmental issues such as climate change, and subsequent behavioural changes (de Leeuw *et al*., 2015; Mills *et al*., 2017). Regarding climate change, personal experiences and beliefs play a crucial role in shaping the implementation of climate change adaptation strategies. However, it is important to acknowledge that beliefs may not always align with the objective reality of climate change. Other factors can influence farmers' opinions about climate change, including the politicisation of climate change by individuals seeking public office, intentionally or unintentionally altering public perceptions and perspectives.

Numerous studies have highlighted that socio-demographic factors and production systems can influence climate change perception (Spence *et al*., 2011; Akerlof *et al*., 2013; Smith & Leiserowitz, 2012; Hitayezu *et al*., 2017; Shisanya & Mafongoya, 2017). Individual attributes of farmers, such as educational background, training, farming experience and age, can shape their perception of climate change (Roco *et al*., 2015). In addition, farmers' perceptions may also be influenced by the climate change beliefs of other farmers within their community (Moyo *et al*., 2012).

Phophi *et al*. (2020) conducted a study in the Limpopo province of South Africa to examine awareness of climate change among smallholder farmers. The findings showed that 85% of the farmers were aware of climate change, with late rainfall, prolonged dry spells, and frequent drought being the primary indicators reported by smallholder farmers. Similarly, Gandure *et al*. (2013) investigated farmers' perceptions of climate change in the Thaba Nchu district of the Free State province in South Africa. Farmers in this region reported changes in their local climate, including increased summer temperatures, freezing winter seasons, reduced precipitation, delayed rainfall, and early cessation. Another study by Shisanya and Mafongoya (2017) in the uMzinyathi district of KwaZulu-Natal of South Africa revealed that 78% of farmers observed increases in both summer and winter temperatures. Farmers also noticed prolonged hot periods and a decrease in the length of cold periods. Interestingly, farmers with access to irrigation infrastructure were less likely to perceive changes in rainfall and temperature. Factors such as farming experience, training, and access to extension services significantly enabled farmers to recognise long-term changes in precipitation.

Hitayezu *et al.* (2017) investigated the socio-psychological factors affecting climate change perceptions among smallholder farmers in the KwaZulu-Natal midlands region. The study identified changes in seasonal climate, such as drier winters, warmer and drier summers, and hotter and wetter winters. It was found that affective impression and egalitarian values significantly influenced farmers' perception of climate change. In addition, trust, education level, and access to climate information enhanced the accuracy of climate change perception.

In the Eastern Cape province of South Africa, Mandleni and Anim (2011) studied climate change perceptions and adaptation among 500 cattle and sheep farmers who had undergone extension training courses. The findings indicated that 86% of the farmers were aware of the region's temperature increases and recurrent drought. The farmers reported harsh weather conditions that led to a decrease in cattle numbers.

In the North West province of South Africa, Oduniyi, Antwi and Nkonki-Mandleni (2018) explored the factors influencing climate change awareness among farmers. The study revealed that farmers in the region were aware of climate change. The study also found that factors such as farm size, education level, access to information on climate change, access to extension services, and the source of farming information played a significant role in determining the level of climate change awareness among farmers.

2.7. DIMENSIONS OF CLIMATE CHANGE RISK PERCEPTIONS

According to Helgeson, van der Linden and Chabay (2012), four key dimensions influence climate change perception. These dimensions are experimental, socio-cultural factors, cognitive, and socio-demographic. The following sub-sections discuss these four dimensions.

2.7.1. Socio-Demographic Factors

Van der Linden (2015) contends that women have a higher probability of perceiving climate change compared to their male counterparts. A possible explanation is that women, coupled with experience, make vivid and intense imageries. Smith and Leiserowitz (2012) also argue that political ideology plays a significant role in climate risk perceptions. It is sometimes assumed that socioeconomic status and higher education levels lead to people perceiving climate change (Akerlof *et al*., 2013). However, Hitayezu *et al. (*2017) found no significant relationship between the level of education, household income and climate change perceptions.

2.7.2. Cognitive Factors

The cognitive aspect of climate change perceptions involves an individual’s knowledge of climate change. Menny *et al*. (2011) present conflicting evidence regarding the relationship between climate change perceptions and knowledge, suggesting that increased knowledge may lead to greater concern for some individuals but not necessarily for others. One limitation of knowledge is its subjectivity, as it relies on self-reported information, making it less reliable (Reser *et al*., 2012). However, other studies (Reser *et al*., 2012) argue that knowledge does play a significant role in climate change perception. Van der Linden (2015) proposes that different forms of knowledge should be considered to understand the role of knowledge in climate change perception fully.

2.7.3. Experiential Processing

Hitayezu *et al*. (2017) suggest that perceptions of climate change based on personal experiences rely on available information and affective heuristics. Pahl *et al*. (2015) argue that individuals tend to give more weight to recent climate events, which are still vivid in their memories, potentially leading to overestimating the severity or risk of climate change. Another aspect of experiential climate risk processing is "affect heuristics" or "risk-as-feelings", which refers to instinctive responses that guide information processing and judgment (van der Linden, 2015). The experience of extreme climatic events, such as prolonged droughts and floods, plays a significant role in shaping perceptions of climate change (Kibue *et al*., 2015). For instance, Spence *et al*. (2011) observed that households that had personally experienced extreme weather events were more conscious of climate change and more willing to adopt adaptation measures. This suggests that first-hand experiences of extreme weather events positively impact individuals' attitudes, leading to a greater willingness to adapt to climate change.

2.7.4. Socio-Cultural Factors

Socio-cultural factors encompass social norms, cultural worldviews, and values, which shape individuals' perceptions of climate change. Social norms refer to the expectations of how people should think, feel, and behave in specific situations (van der Linden, 2015). Worldviews, on the other hand, are individuals' attitudes and perspectives that influence how they perceive and respond to complex situations (van der Linden, 2015). Worldviews consist of four broad components: egalitarianism (values related to equal rights and affirmative action), fatalism (belief in a lack of control over one's future and predetermined events), hierarchism (views about authority and social hierarchy) and individualism (values such as self-reliance and personal independence) (Hitayezu, 2015; van der Linden, 2015). Various studies (Kahan *et al*., 2012; Smith & Leiserowitz, 2012; Akerlof *et al*., 2013) have demonstrated a significant relationship between worldviews and climate change perception. These studies highlight that individuals' worldviews strongly influence their perceptions of climate change.

2.8. ADAPTATION TO CLIMATE CHANGE

According to the IPCC (2018), adaptation to climate change involves voluntary or involuntary processes through which individuals and societies aim to mitigate the adverse effects of climate change. Adaptation typically refers to implementing improvements in procedures, methods, or structures to minimise potential harm or take advantage of opportunities related to climate change (IPCC, 2014). In addition, Chikozho (2010) argues that adaptation is an ongoing process that encompasses behaviours, choices and beliefs influencing decisions across various aspects of life, reflecting current social norms and systems. By enhancing the resilience of rural communities, adaptation significantly reduces vulnerability to climate change and variability, enabling smallholder farmers to cope with the adverse impacts of climate change.

Successful adaptation to climate change by smallholder farmers requires collective action from individuals, society, groups, and governments (Tompkins & Eakin, 2012). It involves understanding the causes and consequences of climate change and the capacity to modify behaviours that contribute to it or may be compromised by potential climate impacts (Niles & Mueller, 2016). The motivation to adapt stems from the desire to protect the well-being and enhance safety. Collaborative efforts at the community level and interactions with higher-level institutions can be crucial in guiding, promoting, and advising the appropriate adaptation strategies for smallholder farmers (Cohen *et al*., 2016). International agreements, such as Article 3 of the United Nations Framework Convention on Climate Change, urge governments to address climate change, emphasising the importance of adaptation. Furthermore, treaties signed at the international level have implications at the local level, where municipalities, industries, economies, and individuals are expected to respond to climate change within the institutional framework and technological and skill capacities available at the local level.

Climate change adaptation in agriculture is a complex and multi-faceted process that occurs at various scales and encompasses different dimensions (Julie, 2014). It occurs within the broader context of climate, economic, technical, social, and political factors, making it difficult to isolate and analyse individual components. Adaptation activities in agriculture serve multiple purposes and are interconnected in nature (Below *et al*., 2012). Farmers' adaptation strategies can be categorised as proactive or reactive. Proactive adaptation involves anticipating potential shocks and mitigating their negative impacts (Robert, Thomas & Bergez, 2016). On the other hand, reactive adaptation refers to actions taken after experiencing a shock or adverse event.

Adaptation can also be classified based on spontaneity, distinguishing between autonomous and planned adaptation. Planned adaptation involves deliberate actions to reduce risks and capitalise on new opportunities arising from global climate change (Le Gal *et al*., 2011; Elum *et al*., 2017). Furthermore, adaptation can be classified based on spatial scope, distinguishing between localised and widespread approaches. It can also be categorised as “form-adaptation”, which includes various dimensions such as behavioural, technological, institutional, financial and informational aspects (Robert *et al*., 2016).

Recognising the need for interventions and support to facilitate adequate adaptation measures, the Kyoto Protocol and the IPCC emphasise the importance of addressing climate change impacts (Elum *et al*., 2017). Several studies (Belay *et al*., 2017; Shisanya & Mafongoya, 2016; Afriyie-Kraft, Zabel & Damnyag, 2020) have suggested various adaptation options for smallholder farmers. These options span different scales (global, regional, and local), involve multiple actors (i.e. farmers, firms, and government), and encompass different types of strategies.

Adaptation options can include market responses, such as income diversification, and individual or farm-level responses, such as crop diversification and adjusting agricultural practices (i.e. timing of operations). Potential adaptation strategies include institutional responses, such as government interventions through subsidies and agricultural market improvements, as well as technological innovations like the introduction of new crop cultivars and advancements in water management techniques (Viljoen, 2014; Jiri *et al*., 2017; Zilberman, Zhao & Heiman, 2012). However, it is essential to note that these adaptation strategies represent potential measures, and their feasibility and likelihood of implementation may vary (Jiri *et al*., 2017). Zuma-Netshiukhwi, Stigter & Walker (2013) describe these possible strategies as "clairvoyant farmer" scenarios, as their successful implementation relies on accurate knowledge of future climatic conditions.

Shisanya and Mafongoya (2016) conducted a study in the uMzinyathi district of KwaZulu-Natal, South Africa, to examine climate change adaptation and its effects on household food security. The study revealed that households expressed concerns about recurring droughts, floods, declining soil fertility, shorter rainy seasons, late onset of rains, and general climate variability. Farmers in the region employed various adaptation strategies, including crop diversification, inorganic fertilisers, agroforestry practices (planting trees alongside crops), cultivation on valley bottoms, and mixed cropping.

Belay *et al*. (2017) conducted a study in the Central Rift Valley of Ethiopia to examine the adaptation strategies employed by smallholder farmers and the factors influencing their choices. The study found that climate change negatively impacted livestock and crop production. To adapt to climate change and variability, farmers implemented various strategies, including on-farm tree planting, crop diversification, soil and water management practices, adjustment of planting dates, adoption of improved crop varieties, and utilisation of agricultural inputs such as fertilisers and pesticides. The ability of farmers to implement effective adaptation measures was influenced by factors such as household demographics, farm size, income, access to extension services and climate information and livestock production. Similarly, a study by Mandleni (2011) in the Eastern Cape province of South Africa revealed that factors such as gender, access to information on climate change and land tenure systems positively and significantly influenced adaptation to climate change.

Studies suggest that social capital plays a vital role in climate change perception and adaptation (Hitayezu *et al*., 2017; Jordaan & Grové, 2013). Social capital enables information sharing, collective action and decision-making by facilitating the transfer of knowledge among farmers (Munasib & Jordan, 2011). In Tanzania, Mulwa *et al*. (2017) found that farmers shared seeds as gifts due to kinship ties, contributing to wider adoption of improved seed use within families. Social capital can act as a mechanism for group dynamics, promoting the exchange of information among farmers and facilitating the adoption of modern technologies. However, among smallholder farmers in South Africa, social capital may primarily be cognitive rather than structural. It is based more on trust, traditions, norms, and values than tangible local organisations and networks (Jordaan & Grové, 2013).

2.9. BARRIERS TO CLIMATE CHANGE ADAPTATION IN SOUTH AFRICA

Numerous studies have identified various barriers to climate change adaptation at the macro and micro levels (Antwi-Agyei, Dougill & Stringer, 2013; Rhodes, Jalloh & Diouf, 2014; Mayaya, Opata & Kipkorir, 2015). At the macro level, challenges include high staff turnover within government departments, resulting in limited understanding and expertise in addressing climate-related issues; the perception of climate change as an environmental problem rather than a developmental issue; matters related to financial management practices; and poor communication and coordination between departments and different levels of government, hindering effective implementation of climate change adaptation strategies (Ziervogel *et al*., 2014). At the micro level, several factors impede the ability of smallholder farmers to adapt to climate change. These factors can be categorised as social, technological, economic, informational, and natural barriers to adaptation (Jones & Boyd, 2011; Masud *et al*., 2017). In a study conducted in the Eastern Cape Karoo region of South Africa by Muller and Shackleton (2014), farmers identified a lack of government support, insufficient funds, inadequate information on climate change and adaptation, and unavailability of long-term weather forecasts as barriers that limit their implementation of adaptation strategies. Mayaya *et al*. (2015) found that farmers in the semi-arid areas of Eastern Africa face several obstacles to climate change adaptation. These include limited resources, insufficient institutional support, inadequate technical assistance, and the challenge of dealing with unpredictable climatic conditions.

2.10. BEHAVIOURAL DECISION-MAKING IN CLIMATE CHANGE PERCEPTION AND ADAPTATION

Climate change adaptation requires pro-environmental behaviour, and understanding farmers' decision-making processes is crucial in promoting such behaviour. Thompson, Reimer and Prokopy (2014) argue that farmers' decisions to engage in climate change adaptation strategies involve weighing the positive and negative impacts based on their attitudes towards economic, environmental, social, and ethical aspects. While financial incentives can motivate farmers, solely focusing on economic benefits does not fully explain their decision-making (Mutyasira, Hoag & Pendell, 2018). Studies applying environmental behavioural approaches (Masud *et al*., 2017; Jellason *et al*., 2019; Mills *et al*., 2017) have demonstrated a connection between attitudes, perception of environmental issues, and behavioural change. Best (2010) suggests that farmers' underlying belief system and values related to environmental concerns shape their perceptions and influence their choices. Social psychological perspectives have also been employed to analyse decision-making (Poppenborg & Koellner, 2013; De Snoo *et al*., 2013). These studies found that farmers' attitudes and self-perception as conservationists influenced their efforts in environmental conservation.

Mills *et al.* (2017) investigated farmers' willingness to adopt environmental management practices in the United Kingdom. The findings revealed that farmers' personal beliefs played a crucial role in explaining the extent of environmental management, as those with stronger environmental values were more likely to implement such measures. Similarly, in the highland's regions of Ethiopia, Mutyasira *et al*. (2018) found that personal norms and intentions were predictors of sustainable agricultural practices adopted by smallholder farmers. Self-identity holds significant importance in the decision-making process. Terry, Hogg and White (1999) defines self-identity as the extent to which an individual's behaviour is considered integral to their sense of self. When an identity is more salient, it is more likely to guide and predict one's actions (Hyland *et al*., 2015). Understanding farmers' sense of identity regarding environmental issues is crucial in determining their motivation to participate in and adopt climate change adaptation strategies (Sulemana & Jones, 2014).

In recent times, heightened awareness of climate change has prompted a call for interdisciplinary approaches to comprehensively grasp both the biophysical ramifications and the human facets of this phenomenon. Household behaviour is a complex, multidimensional phenomenon that is compounded by the addition of environmental concerns. The Theory of Planned Behaviour, as described in Chapter 1, is a widely used model to explain households' environmental behaviour (Yee, Al-mulali & Ling, 2022). The theoretical framework of this study incorporates several key constructs related to behavioural intentions and actions. Firstly, subjective norms gauge an individuals' perception of the social pressure exerted upon them to engage in specific behaviours. This construct reflects the extent to which individuals feel responsible for conforming to external opinions that shape their actions. In addition, perceived behavioural control (PBC) is a pivotal component, encompassing an individuals' belief regarding their capability to execute a particular behaviour (Wang, Zhang, Xiao, Sun, Xiao & Shi, 2020). This belief is grounded in their assessment of personal abilities as well as external factors that may influence their actions (Ibrahim, Mariapan, Lin & Bidin, 2021). These three aforementioned variables, namely subjective norms, perceived behavioural control, and behavioural intention, collectively contribute to the determination of ones' intention to engage in a specific behaviour. It is worth noting that this intention, in turn, exerts a direct influence on actual behavioural outcomes.

Among the frameworks examined for the analysis of pro-environmental behaviour, the earliest and most straightforward models posited a linear progression from environmental knowledge to environmental awareness and concern (Masud *et al*., 2017). The theoretical underpinning of pro-environmental behaviour posited that enhancing public awareness of environmental issues would inherently lead to an increase in pro-environmental actions. The widespread perception of individuals as having limited efficacy in mitigating and adapting to evolving anthropogenic climatic conditions is closely associated with an inadequate understanding of the nexus between human conduct and the causal factors of climate change. Consequently, the lack of knowledge emerges as a significant cognitive obstacle that confronts communicators and educators in the realm of climate change. It is imperative that climate communication research address the cognitive, social-psychological, and behavioural impediments to human adaptation with a sense of urgency (Arli, Bodejo, Carlini, France, Jebarakakirthy, Knox, Pentecost, Perkins, Thaichon & Sarker, 2019).

2.11. SOUTH AFRICA'S RESPONSE TO CLIMATE CHANGE

In commemorating its seventieth anniversary, the United Nations member states embraced the Sustainable Development Goals (SDGs), a comprehensive global plan for achieving a sustainable future encompassing 17 goals and 169 targets to be accomplished by 2030 (United Nations, 2016). These ambitious international commitments marked the beginning of a new era in sustainable development known as the “post-2015” era. These goals strive for transformative change in the face of important social, economic, political, and environmental challenges. As a member of the United Nations, South Africa has also embraced the Sustainable Development Goals (SDGs). Goal 2 focuses on “ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture,” with target 2.4 specifically aiming to ensure sustainable food production systems, resilient agricultural practices, and enhanced capacity for adaptation to climate change, extreme weather events, and natural disasters by 2030. Furthermore, Goal 13 emphasises the need for all nations to urgently address climate change and its impacts. Specifically, target 13.1 of Goal 13 aims to enhance resilience and adaptive capacity to climate-related hazards and natural disasters across all countries (United Nations, 2016).

While the relationship between climate change consequences, climate action, and sustainable development is widely acknowledged, there has been limited systematic research on the synergies and trade-offs associated with specific targets within the Sustainable Development Goals (SDGs). The IPCC published the Special Report on Global Warming of 1.5°C, which explores the connections between climate mitigation, adaptation efforts, and the 17 SDGs (IPCC, 2018). While this report provides valuable insights, it does not comprehensively analyse the specific synergies and trade-offs between the impacts of climate change, climate action, and all 169 targets outlined in the 2030 Agenda.

With the changing environment and the significant impact of climate change on millions of smallholder farmers, there is a substantial risk of jeopardising their livelihoods and food security. In addition, South Africa has high per capita emissions compared to other countries in Africa and globally. Initially, climate change in South Africa was predominantly seen as an environmental concern rather than a developmental issue (Ziervogel *et al*., 2014). However, following the country’s first national communication to the United Nations Framework Convention on Climate Change (UNFCCC) in 2001, there was a shift towards a clear adaptation and mitigation plan, both in national policy and UNFCCC negotiations. This transition was highlighted in 2005 during the ‘Climate Action Now’ National Climate Change Summit, which featured integrated sessions on science and policy. Subsequently, the National Climate Change Response White Paper and South Africa's National Communication strategy were developed as outcomes of the National Climate Change Summit (Ziervogel *et al*., 2014).

During the 2005 Climate Change Summit, the government proposed and initiated research that led to the creation of Long-Term Mitigation Scenarios. These scenarios served as a basis for developing various policies, such as the Independent Power Producer Procurement Programme for Renewable Energy. More recently, the National Treasury has been exploring the implementation of carbon taxes, demonstrating a proactive response to the identified scenarios. In 2018, the Department of Environmental Affairs and Tourism accelerated these efforts by issuing a climate bill for public consultation, indicating an ongoing commitment to addressing climate change.

The National Climate Change Response Policy (NCCRP) is a comprehensive national policy framework for addressing climate change in South Africa. It is outlined in the National Climate Change Response White Paper (NCCRWP) published in 2011. The NCCRWP draws guidance from various sources, including the South African Constitution (Section 241, the Bill of Rights), the National Environmental Management Act (No. 107 of 1998), the agreements of the United Nations Framework Convention on Climate Change (UNFCCC), and the Millennium Agreement. In June 2018, a public engagement campaign was initiated to gather feedback on a draft Climate Change Bill to establish specific objectives and regulations for climate change. The proposed bill sought to enable an effective response to climate change, promote a just transition to a climate-resilient and low-carbon economy and society and align with principles of environmentally sustainable development. In addition, the Disaster Management Amendment Act (No. 16 of 2015) includes provisions for implementing disaster risk mitigation measures, including climate change adaptation and the development of early warning systems.

In 2017, a draft National Climate Change Adaptation (NCCA) strategy was released; however, it has yet to receive endorsement from Cabinet. Although South Africa has progressive climate change policies in place, there have been challenges in implementing them effectively. These challenges include policy alignment, coherence, and coordination; complexities and continuity in policy implementation; difficulties in public-private engagement and consultation; gaps and constraints in information and data availability; and limited capacity among municipal staff. Despite the country's commitment to enacting climate change legislation, studies indicate that South Africa is still confronted with development issues such as poverty, limited access to essential services, and a high unemployment rate.

The National Development Plan (NDP) plays a significant role in guiding the country’s development, and it recognises agriculture to uplift farming communities from poverty.

Chapter 5 of the NDP emphasises the importance of transitioning to a low-carbon economy in response to climate change. The plan acknowledges that South Africa is vulnerable to the impacts of climate change, posing substantial risks to livelihoods, health, water, and food security, especially for marginalised groups such as people experiencing poverty, women, and children (National Planning Commission, 2012). However, despite this recognition, disadvantaged communities still face vulnerability to environmental risks and the challenges associated with a resource-based economy (National Planning Commission, 2012). South Africa's capacity to effectively address climate change is hindered by social vulnerability, dispersed and inadequately planned development, and insufficient infrastructure (National Planning Commission, 2012). As a result, the NDP has achieved limited success in combating climate change through systematic climate-specific measures.

In response to the challenges posed by climate change, the province of KwaZulu-Natal has formulated the Provincial Growth and Development Strategy (PGDS). The PGDS acknowledges the region's environmental sustainability is at risk due to erratic and severe weather conditions, including droughts, floods, intense storms, and unsustainable land-use practices. To address these issues, the strategy emphasises the need to enhance ecosystem services' resilience, promote green technology adoption, and implement effective climate change adaptation and response measures (PGDS, 2016).

2.12. SUMMARY

This chapter has discussed the concept of climate change, its causes, and its implications for smallholder farmers. Based on various studies, greenhouse gases like carbon dioxide, nitrous oxide, and methane have been identified as the primary contributors to global warming. Over the past century, global temperatures have risen while average rainfall has decreased. These climate changes have had a profound impact on the livelihoods of smallholder farmers. Excessive heat has altered the growing seasons, and prolonged droughts have led to crop failure and loss of livestock. These climate change effects exacerbate the existing challenges faced by smallholder farmers. Adapting to the negative impacts of climate change is a two-step process for farmers. Firstly, farmers need to recognise and perceive the changes in the climate. Secondly, farmers must identify and adopt appropriate adaptation strategies. Therefore, farmers' ability to perceive climate change is a prerequisite for effective adaptation. Adaptation measures can be implemented at both macro and micro levels. The review presented in this chapter has demonstrated that farmers do perceive climate change and have implemented various adaptation strategies such as tree planting, adjusting planting dates, practising intercropping, employing soil and water conservation techniques, and utilising inorganic fertilisers. In response to climate change, the South African government has developed policies to mitigate the adverse effects of climate change.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter provides an overview of the methodology employed to collect and analyse survey data. It starts by revisiting the research objectives that guided the investigation and offers a comprehensive description of the study area, including its location, climate conditions, and socioeconomic and demographic characteristics. The rationale behind selecting the study site is also explained, along with details about the sampling procedures and the tools used for data collection. A brief outline of the data analysis methods is also provided in this chapter. The last section summarises the chapter.

3.2. RESEARCH OBJECTIVES

The following research objectives address the research problem in this study:

i. Examine perceptions of smallholder farmers on climate change using information from smallholder farmers over a 20-year (1999-2019) production season.
ii. Identify socioeconomic determinants of smallholder farmers' perceptions of climate change.
iii. Determine the perceived impact of climate change on smallholder farmers' livelihoods.
iv. Analyse the determinants of farmers' choice of climate change adaptation strategies.

3.3. STUDY AREA DESCRIPTION

3.3.1. Location of the Study Area

UMkhanyakude district municipality is situated in the northern part of the KwaZulu-Natal province, South Africa, at coordinates 32.014489° latitude and -27.622242° longitude (uMkhanyakude District Municipality, 2018). The district borders the Indian Ocean to the east, Mozambique to the north, the Kingdom of eSwatini to the northwest, and the uThungulu and Zululand districts to the south and west. The district comprises five local municipalities: Jozini, uMhlabuyalingana, Hlabisa, Mtubatuba, and Big Five False Bay. UMkhanyakude is predominantly a rural district, with Mtubatuba and Jozini as major local towns. Covering an area of 12 818 km^2, the district has a population of approximately 625 846 people, resulting in a population density of 46 individuals per km^2 (uMkhanyakude District Municipality, 2018). In terms of size, uMkhanyakude is the second-largest district in KwaZulu-Natal. Figure 3.1

depicts the location of uMkhanyakude district within the KwaZulu-Natal province of South Africa.

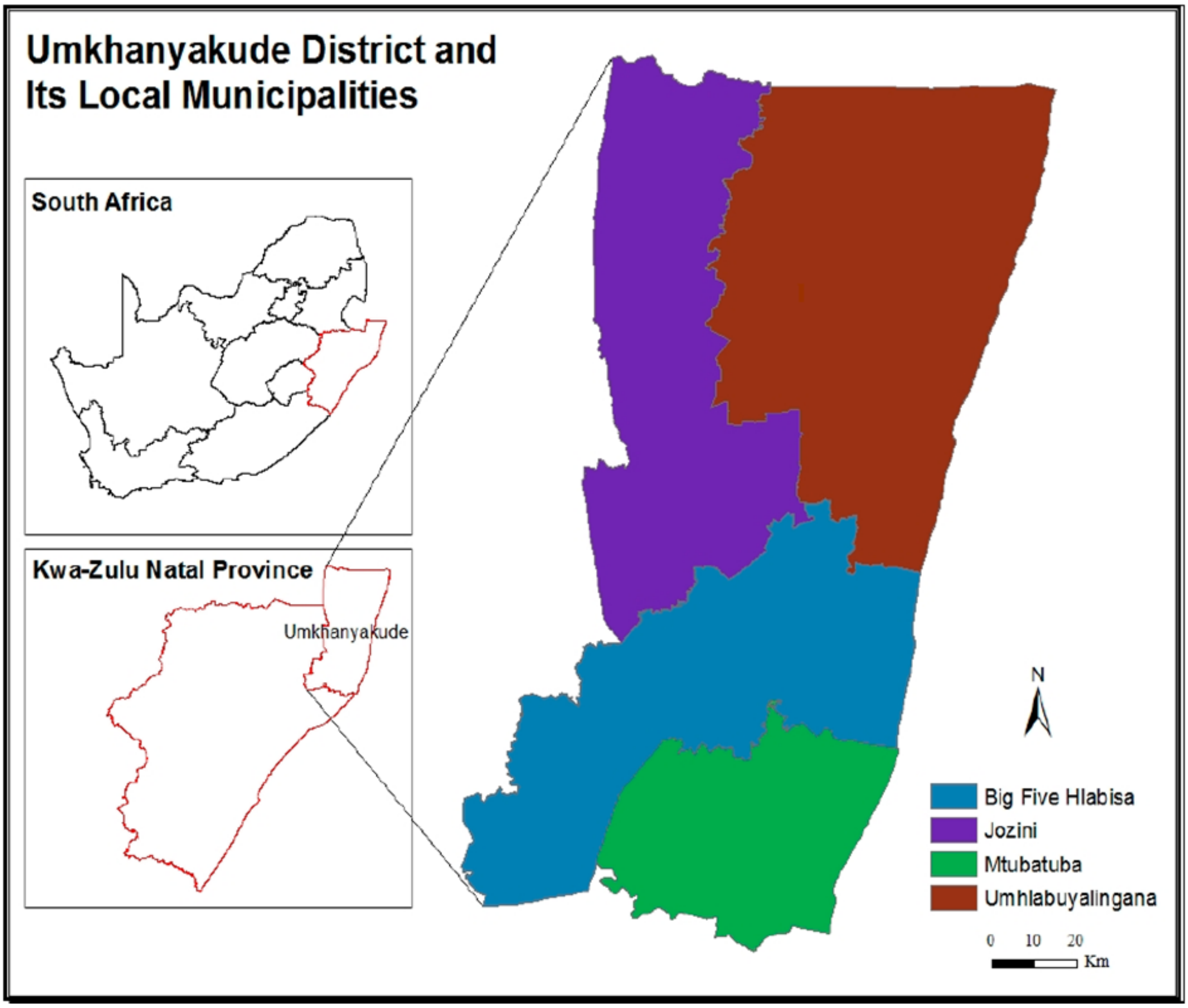

Figure 3.1: Location of study area- uMkhanyakude district municipality of KwaZulu-Natal

Source: uMkhanyakude District Municipality (2018)

UMkhanyakude district experiences a sub-tropical climate characterised by hot and humid summers from November to March and colder and drier winters spanning from June to August (Lankford *et al*., 2011). The region is also known for its aridity. The hydrologic network of the district includes rivers such as Ingwavuma and Pongola, streams, dams (i.e., Pongola), and ponds. Jaganyi, Salagae and Matiwane (2008) analysed rainfall data from 1962 to 2004, the average annual precipitation for the region was estimated at 690 mm, with a maximum of 1341 mm and a minimum of 376 mm. Climate change has become a significant concern in KwaZulu-

Natal, particularly in the uMkhanyakude district. Recent climate forecasts for the region indicate potential adverse effects on rain-fed agriculture, including lower annual rainfall, higher temperatures, increased hydrological risks, greater rainfall variability, soil drying, reduced plant water availability, and heightened irrigation demands (uMkhanyakude District Municipality, 2018).

3.3.2. Climate in the uMkhanyakude District (1999-2019)

The observed annual rainfall ranges from 514 mm (1999) to 525.9 mm (2019), and the average rainfall for the 20-year period is 584.45 mm. Figure 3.2 shows the rainfall patterns of the uMkhanyakude district for the period 1999-2019. The rainfall trends in Figure 3.2 shows that rainfall is decreasing in the district. The year 2000 received the most rainfall (836 mm above average), while 2002 received the least rain (252 mm below average). The years 2000, 2001, 2004, 2006, 2007, 2009, 2012, 2017 and 2018 received above-average rainfall, 1420.6 mm, 702 mm, 704.4 mm, 827 mm, 619 mm, 647 mm, 707.7 mm, 604.1 mm, and 652.3 mm, respectively. Conversely, the years 1999, 2002, 2003, 2005, 2008, 2010, 2013, 2014, 2015, 2016 and 2019 recorded below-average rainfall, 514 mm, 332 mm, 352.5 mm, 491.7 mm, 415mm, 476 mm, 472.6 mm, 571.3 mm, 453 mm, 396.5 mm, 388.9 mm, and 525.9 mm, respectively. Since South Africa is a semi-arid country, the decreasing average annual rainfall threatens smallholder farmers' livelihoods. These farmers heavily rely on rainfed agriculture for their crop and animal production. The decline in rainfall puts their agricultural activities at risk and potentially jeopardises their livelihoods.

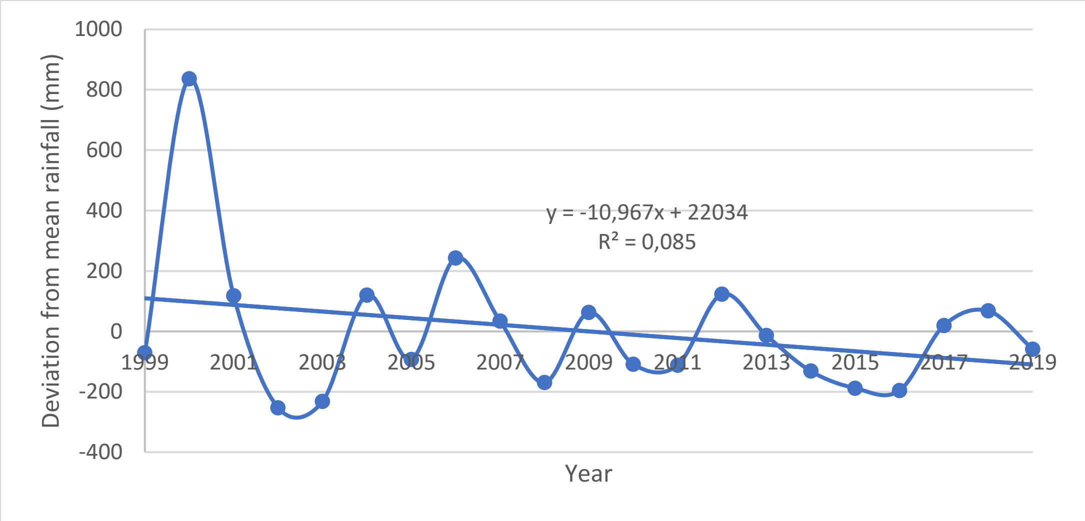

Figure 3.2: Annual Deviation of Rainfall from the Mean in uMkhanyakude District (1999-2019)

Source: South African Sugarcane Research Institute Meteorological Data

In general, meteorological records indicate that minimum and maximum temperatures have been slightly increasing in the uMkhanyakude district over the period 1999-2019 (Figure 3.3) and the year 2013 recorded the lowest minimum temperature (14.70 °C), while the highest annual minimum temperature (16.20 °C) was recorded in 2019. 2009 recorded the least maximum temperature (27 °C), whereas 2019 recorded the most maximum temperature (29 °C).

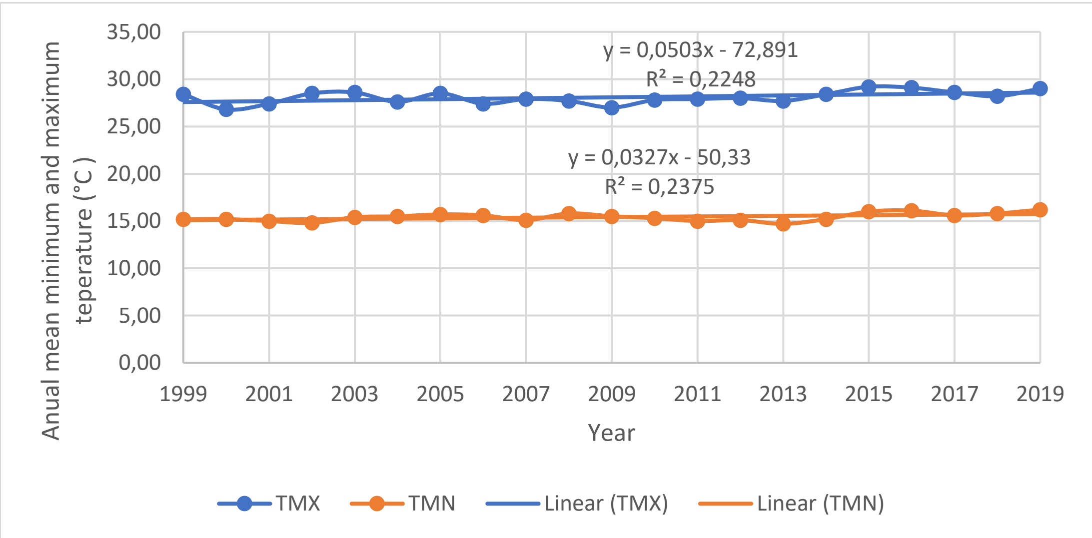

Figure 3.3: Annual Minimum and Maximum Temperature in uMkhayakude district (1999-2019)

Source: South African Sugarcane Research Institute Meteorological Data

3.3.3. Land Capability in uMkhanyakude District

Agriculture is one of the major economic drivers in the district. A large section of the district's territory, mainly on the eastern side of uMkhanyakude, offers excellent agricultural potential. About 20% of the district has tremendous potential for agricultural operations, with the other 52% having medium potential (uMkhanyakude District Municipality, 2018). Unsustainable land uses, inadequate agricultural methods, and land reform has all been identified as threats to the land with high agricultural potential.

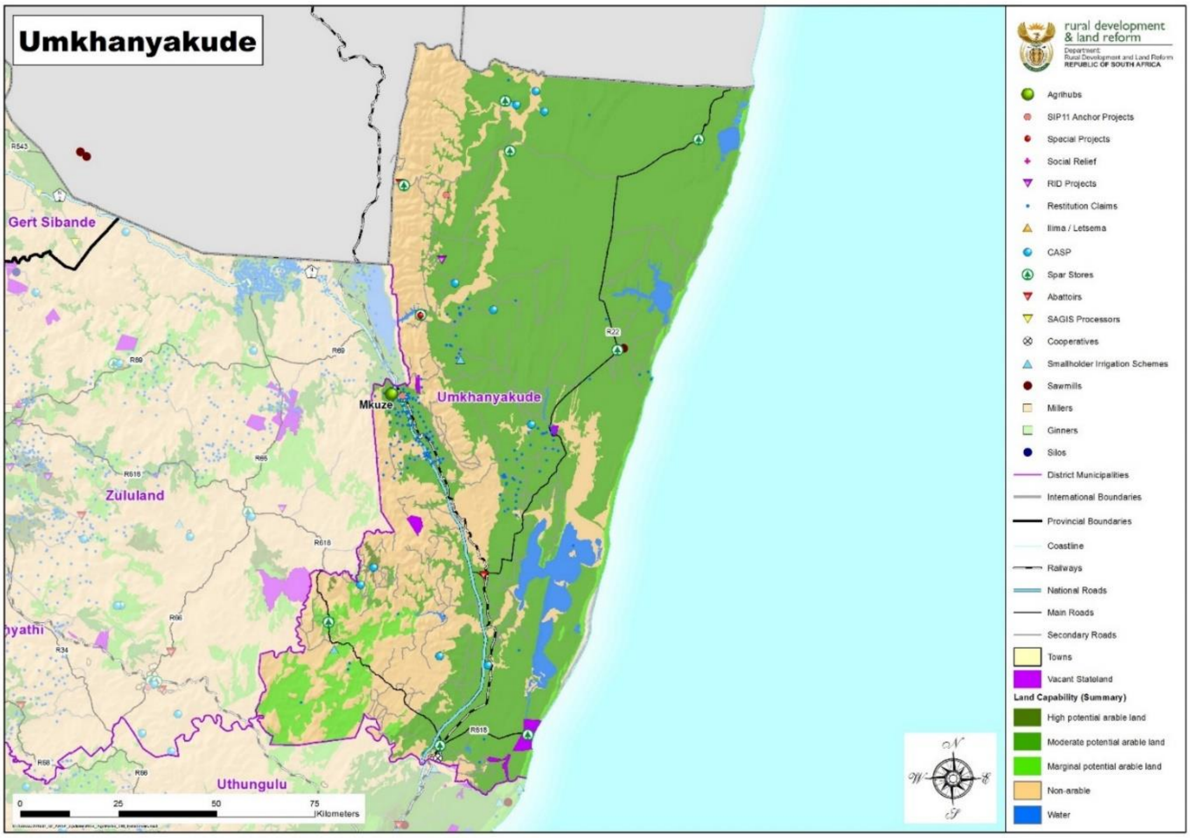

Figure 3.4: Land Capability in uMkhanyakude District

Source: Department of Rural Development and Land Reform

3.3.4. Population Characteristics and Economic Activities

Population estimates from Stats SA (2020) suggest that South Africa has a total population of approximately 59.62 million people, with 19.6% residing in the province of KwaZulu-Natal. Within KwaZulu-Natal, uMkhanyakude district is home to an estimated 689 090 people, accounting for 6.2% of the province's population (Stats SA, 2018). Among the population in uMkhanyakude district, approximately 40.9% are children aged 0-14 years, while the youth comprise 37.8% of the population (Stats SA, 2018).

Regarding socioeconomic status, uMkhanyakude district is one of the poorest regions within the province of KwaZulu-Natal. Most (85.2%) of municipal households earn less than R1 600 per month (uMkhanyakude District Municipality, 2012). The area has been characterised by acute poverty and limited economic development, with rural development in northern KwaZulu-Natal being neglected. Traditional materials and techniques are used for building homesteads, and the local population relies on wood as a fuel source for cooking. Many households lack access to electricity, and sewage systems, and rely on public taps or nearby rivers, often located kilometres away from their homes, for water supply.

Agriculture plays a pivotal role in the development of uMkhanyakude district. Most of the people in the district are rural dwellers (uMkhanyakude District Municipality, 2018). Many households in the district depend partly on subsistence agriculture to fulfil their food needs. The crops commonly grown by these households include maize, beans, sweet potatoes, and cassava.

The eastern part of uMkhanyakude district is characterised by land with a high agricultural potential. Approximately 20% of the district's land has high agricultural potential, while 52% is classified as having medium potential (uMkhanyakude District Municipality, 2018). However, the land with high agricultural potential faces threats from unsustainable land use practices and poor farming methods. It is crucial to address these issues to ensure the long-term sustainability and productivity of agricultural activities in the district.

3.4. DATA COLLECTION METHODS

This study used a mixed-method approach, incorporating both quantitative and qualitative data collection methods. Quantitative data was obtained through a survey that involved administering a structured questionnaire to the participants. On the other hand, qualitative data was gathered through focus groups and key informant interviews. The sampling design and data collection tools used in this study are outlined in the following sub-sections.

3.4.1. Sampling

Quantitative data was collected between in August 2020 using a pre-tested structured questionnaire administered by trained and experienced enumerators. The uMkhanyakude district was purposively chosen from the 11 districts in KwaZulu-Natal because it is the most arid district with a significant population of smallholder farmers. The study targeted smallholder farmers involved in crop and animal production, either for their own food consumption or for selling a surplus.

Data was collected from two local municipalities (LMs), Jozini and uMhlabuyalingana. These two LM has the highest number of farming households in the uMkhanyakude district. Jozini LM has a population of 198 215 and is comprised of 44 584 households (Stats SA, 2016). UMhlabuyalingana LM is home to 172 077 people and has 39 614 households (Stats SA, 2016). In total, the selected LMs have 84 198 households; 53% of the households are from Jozini LM, while the remaining 47% are from uMhlabuyalingana LM. These two LMs have the highest number of households in the uMkhanyakude district (Stats SA, 2016). The sample size for this study was determined based on the guidelines provided by Israel (1992). Based on the guidelines, sample sizes of 370, 383, and 384 would have a 5% margin of error on a 95% confidence level for population sizes of 10 000, 100 000, and 500 000, respectively. A sample size of 400 households was deemed sufficient for this study.

Smallholder farmers were randomly selected using a stratified sampling procedure. In the first stage, 50% of the wards in each local municipality were randomly sampled. Jozini LM has 20 wards, while uMhlabuyalingana LM has 18 wards. Nine wards were randomly selected from uMhlabuyalingana LM, while 10 wards were selected from Jozini LM. In the second stage, 400 farming households were randomly selected from the two LMs. Out of the 400 farming households, 212 (53%) were from Jozini LM and the remaining 188 (47%) farming households were sampled from uMhlabuyalingana LM.

3.4.2. Questionnaire

Studies on the landscape (Yu *et al*., 2013) and climate change adaptation (Below *et al*., 2012) have demonstrated the robustness of the survey approach. In this study, quantitative data were collected using a structured questionnaire. The questionnaire was specifically designed to gather information on various aspects, including demographics (such as age, gender, level of education, family size, and income), crop production, household assets, livestock ownership, support services and farmer training, land ownership, climate change perceptions, climate change adaptation strategies, and household food security status.

A pre-test was conducted to ensure the reliability and coherence of the survey questionnaire on four non-sampled households in the Jozini LM of the uMkhanyakude district. The five non-sampled households were randomly selected from the Ndumo area, and the questionnaire was administered to farmers. Based on the pre-test results, modifications were made to the questionnaire so that the final questionnaire is coherent and easy to administer.

Before the actual data collection, enumerators were trained to familiarise themselves with the modified questionnaire. During the data collection process, the trained enumerators interviewed the smallholder farmers and filled out the questionnaires on their behalf. This direct communication with the farmers ensured clarity and understanding of the questionnaire's questions, as the enumerators could provide necessary explanations or clarifications.

In cognisance of the Covid-19 pandemic, face masks were mandatory for all enumerators. The survey was conducted when community transmission was low in the study areas. Enumerators were screened daily for temperature variation, and enumerators whose temperature was abnormally low or high were not allowed to interview farmers. Enumerators maintained a two-metre distance from the participants while conducting the interviews. Hand sanitisers were made available for each enumerator.

3.4.3. Focus Group Discussions (FGDs)

The focus group approach is a valuable method for collecting qualitative data, as it involves gathering a small number of individuals in an informal setting to delve into specific topics of interest (Onwuegbuzie *et al*., 2009). Focus groups are a well-suited tool for gathering qualitative data and have been widely used across various disciplines and contexts to explore diverse issues (Colucci, 2007). This study conducted focus group discussions to obtain in-depth information regarding farmers' experiences of climate change, their adaptation strategies, and the impact of climate variability and change on their livelihoods. Following the recommendation of Tang and Davis (1995), each focus group consisted of a maximum of 12 farmers. This group size was appropriate to facilitate maximum participation and encourage open and meaningful discussions. Two focus groups were conducted, one in the Jozini Local Municipality and one in the uMhlabuyalingana Local Municipality. A limitation of focus groups is that introverted personalities find it difficult to voice their opinions freely. To stimulate discussion, participants were pointed at random so that group members can equally participate.

Focus groups were held outdoors to ensure proper ventilation; this ensured the safety of the farmers from Covid-19 infection. The focus groups were conducted when community transmission was low in the study areas. All participants in the focus groups were screened before the meeting. An infrared thermometer was used to check temperature, and participants with abnormal temperatures were not allowed into the focus group. Hand sanitisers, soap and water were available in every focus group. Participants in the focus groups were given face masks they were encouraged to wear during the meeting. Participants kept a two-metre distance between each other during the session. Farmers with pre-existing medical conditions and over 65 did not form part of the focus groups.

3.4.4. Key-Informant Interviews

Key informants who possess in-depth knowledge of the community were selected to provide valuable insights on climate change, adaptation strategies, and the effects of climate change on the livelihoods of smallholder farmers in the local municipalities. The key informants included ward councillors, animal health technicians, members of traditional local councils, agricultural extension officers and representatives from Non-Governmental Organisations (NGOs). A key informant interview guide was employed to ensure an organised and focused interaction. Considering the need to prioritise safety during the COVID-19 pandemic, the key informant interviews were conducted telephonically to minimise contact and the potential spread of the virus. Table 3.1 below shows the distribution of key informants that were interviewed.

Table 3.1: Key Informants used in the Study

Type of key informant	Number
Extension officers	2
Tribal authorities (local herdman)	2
Representatives from NGOs	3
Total	**7**

3.4.5. Meteorological Data

Meteorological data from the Makhathini Agricultural Research Station (Jozini) was used to analyse the study area's rainfall, temperature, and humidity trends from 1999 to 2019. This data was compared with community perceptions to determine if there is an alignment between the scientific measurements and the local community's perceptions regarding temperature, rainfall, and humidity patterns.

3.5. DATA ANALYSIS

Quantitative data was captured in SPSS (Statistical Package for Social Sciences version 21, 2012), cleaned, and then transferred to STATA (Version 15, 2017) for analysis. Table 3.2 summarises the objectives and data analysis methods. Detailed data analysis approach for each objective is outlined in the subsequent chapters.

Table 3.2: Summary of Objectives and Method of Data Analysis

Objectives	Data analysis method
Examine smallholder farmers' perceptions on climate change using information from smallholder farmers over a 20-year (1999-2019) production season.	Descriptive statistics Principal Component Analysis (PCA)
Identify socioeconomic determinants of smallholder farmers' perceptions of climate change.	Descriptive statistics Binary logistic regression model
Determine the perceived impact of climate change on smallholder farmers' livelihoods.	Descriptive statistics Thematic analysis
Analyse the determinants of farmers' choice of climate change adaptation strategies.	Descriptive statistics Multinomial logistic (MNL) regression model

3.6. ETHICAL CONSIDERATIONS

The study followed the ethical guidelines of the University of the Free State, ensuring that informed consent and confidentiality were maintained throughout the research process. This involved providing participants with verbal briefings, information, and consent forms. Prior permission was obtained from the KwaZulu-Natal Department of Agriculture and Rural Development and local tribal authorities. Fieldworkers were trained to explain the purpose of the study, obtain informed consent from potential respondents, and provide factual and neutral information about the rights and benefits of participation without coercion. Participants were free to choose whether to participate and were fully informed about the potential risks and rewards of participation, the limits to confidentiality, and the use of the information provided. Persons under 18 (minors) were not allowed to participate in this study.

3.7. SUMMARY

This chapter has provided an overview of the study area, the methodology employed for data collection and the analytical techniques used to analyse quantitative and qualitative data. The study used a mixed method approach, employing a structured questionnaire for quantitative data collection and employing focus groups and key informant interviews for qualitative data collection. Quantitative data was collected from 400 smallholder farmers in the uMkhanyakude district. The analytical methods employed included principal component analysis, a multinomial logistic regression model, and the binary logistic regression model for the quantitative data. At the same time, thematic analysis was used to analyse qualitative data. These analytical tools were chosen to comprehensively understand farmers' perceptions and adaptation to climate change. The subsequent four chapters will present the findings of the research.

CHAPTER 4: PERCEPTIONS OF SMALLHOLDER FARMERS ON CLIMATE CHANGE IN THE UMKHANYAKUDE DISTRICT

4.1. INTRODUCTION

In South Africa, it is estimated that there are 2.4 million agricultural households and 43.7% of these households engage in agriculture to secure additional food sources (Stats SA, 2016). These farmers heavily rely on a dryland farming system, which is particularly susceptible to the impacts of climate change and variability (Kotir, 2011). South Africa is classified as a semi-arid country, receiving an average annual rainfall of approximately 450 mm, significantly lower than the global average of 860 mm (Botai, Botai & Adeola, 2018). Over the years, recurring droughts have been a significant occurrence in various regions of South Africa, spanning from the late 1970s to 2017 (Mahlalela *et al*., 2020). For instance, between 2014 and 2016, the country experienced its most severe drought in decades, leading to the declaration of five provinces as drought disaster areas (Botai *et al*., 2018). The already elevated poverty levels and limited adaptive capacity further compound the vulnerability of farming households (Mudombi, Nhamo & Muchie, 2014). According to the former Department of Environmental Affairs (DEA, 2011), at least 30% of South African households were exposed to climate change shocks.

Several studies conducted in South Africa have highlighted the various ways in which smallholder farmers perceive changes in the climate. According to Spence *et al*. (2011), these perceptions include prolonged periods of drought, rising temperatures, reduced rainfall, and frequent flooding occurrences. Hitayezu *et al*. (2017) conducted a study in the midland's region in KZN. The study found that 68% of surveyed farmers observed changes such as colder and drier winter seasons, hotter and drier summer seasons, and unusually warmer and wetter winter seasons. In the Limpopo province, farmers identified recurring drought, delayed rainfall, and extended dry spells as indicators of climate change (Phophi *et al*., 2020). Another study by Mandleni and Anim (2011) in the Eastern Cape province revealed that farmers held diverse perceptions of climate change, categorised into themes such as drought and windy weather patterns, information and adaptation, climate change extension services, intensive cattle and sheep production, and temperature changes.

Farmers' perceptions of climate change play a crucial role in shaping their responses to climate risks, ultimately influencing their adaptation strategies (Debela *et al*., 2015). Climate change studies conducted in the uMkhanyakude district have mainly focused on households coping strategies on climate change (i.e. Patrick, 2020; Patrick, 2021). This study aims to close this gap by investigating climate change perceptions in the uMkhanyakude district. These perceptions serve as a foundation for climate change adaptation. Consequently, if there are misconceptions regarding climate change, it can lead to maladaptation or a failure to adapt, thereby increasing the risks associated with the adverse effects of climate change (Debela *et al*., 2015). Exploring farmers' perceptions of climate change is valuable as it provides insights into the unpredictable nature of environmental changes (Bomuhangi, Nabanoga & Namaalwa, 2016). These perceptions, unlike general circulation models (GCMs), reflect the concerns of farming households that broader climate models may not capture. In addition, the knowledge gained from understanding farmers' perceptions can inform policymaking and aid in developing adaptation strategies tailored to the specific needs of local communities.

This chapter analyses the perceptions of smallholder farmers on climate change in the uMkhanyakude district. The subsequent sections of this chapter are organised as follows: The second section provides an overview of the methodology employed for data analysis. The third section presents the results and discussion. Finally, the concluding section summarises the chapter.

4.2. ANALYTICAL METHODS

4.2.1. Principal Component Analysis (PCA)

In this study, the principal component analysis (PCA) technique was employed to analyse the prevailing perceptions of farmers regarding climate change and variability. PCA is a widely used transformation technique that reduces a complex set of variables into a simplified canonical form (Essa & Nieuwoudt, 2003; Mandleni & Anim, 2011; Sinyolo, Mudhara & Wale, 2014). The purpose of using PCA in this study was to identify interrelated variables and explore their underlying relationships (Manley, 1990 as cited in Mandleni & Anim, 2011). By employing PCA, this study aimed to uncover hidden interrelationships within the variables and gain insights into the farmers' perceptions of climate change. Following Mandleni and Anim (2011), the criterion can be described as follows:

$PC_1 = a_{12}X_1 + a_{13}X_2 + ... + a_{1m}X_m$

$PC_2 = a_{23}X_1 + a_{24}X_2 + ... + a_{2m}X_m$

$PC_m = a_{m1}X_1 + a_{m2}X_2 + ... + a_{mm}X_m$

Where m variable X_1, $X_2 \ldots X_m$ is observed on *n* smallholder farmers; a_{12}, $a_{13} \ldots a_{1m}$ are the coefficients generated so that the first PC, i.e., PC_1, accounts for the maximum contribution to the variance in the *m* number of variables in the analysis. Thus, the set of variables $X_1, X_2 \ldots X_m$ is transformed into a given set of orthogonal variables that accounts for as much variation as possible in descending order (Nieuwoudt, 1977). The generated set of variables results from a linear combination of the original variables. The second principal component (PC_2) is not correlated to the first principal component (PC_1) and captures the maximum remaining variable variation. Similarly, subsequent components are uncorrelated with the preceding components and explain a decreasing variation in the original variables (Sinyolo, 2016). As proposed by Jeffers (1967), principal components with eigenvalues exceeding one were selected for further analysis. A limitation of PCA is that it is not robust to missing values, PCA may not work properly or produce inaccurate results if the data has gaps. To counter this problem, missing values were imputed in the dataset.

Eigen vectors or eigenvalues of the covariance matrix give weights to each principal component (PC). In principal component analysis (PCA), the goal is to have most of the principal components' eigenvalues be very small or close to zero. This implies that only a few principal components are needed to explain the variation in the dataset. In contrast, the eigenvalues that are not negligible are the ones contributing significantly to the variation. Table 4.1 provides an overview of the variables related to livelihoods used in the PCA, along with their descriptions and proportions.

Table 4.1: Description of Livelihood-Related Variables Used in the Principal Component Analysis

Variable code	Variables name and description	Proportion
POOR_LIVEPRO (X_9)	Poor livestock production	
	Yes	0.85
	No	0.15
DECREASE_CROPY (X_{10})	Decrease in crop yields	
	Yes	0.22
	No	0.78
LOSS_ASSETS (X_{11})	Loss of assets	
	Yes	0.68
	No	0.32

Climate variables used in the principal component analysis are presented in Table 4.2. These variables include changes in temperature, changes in rainfall, frequency of drought, frequency of floods and strong winds.

Table 4.2: Description of Climate Variables Used in the Principal Component Analysis

Variable code	Variables name and description	Proportion
TEMPERATURE_CHANGE (X_4)	Temperature Changes	
	Yes	0.94
	No	0.06
RAINFALL_CHANGE (X_5)	Rainfall changes	
	Yes	0.95
	No	0.05
DROUGHT_FREQ (X_6)	Frequency of drought	
	Increased	0.71
	Decreased	0.20
	Stayed the same	0.07
	I do not know	0.02
FLOODS_FREQ (X_7)	Frequency of floods	
	Increased	0.12
	Decreased	0.65
	Stayed the same	0.13
	I do not know	0.09
STRONG_WINDS (X_8)	Strong winds	
	Increased	0.71
	Decreased	0.20
	Stayed the same	0.05
	I do not know	0.04

Table 4.3 presents the institutional variables used in the principal component analysis. These include farmer training, general extension services and extension services focusing on climate change.

Table 4.3: Description of Institutional Variables Used in the Principal Component Analysis

Variable code	Variables name and description	Proportion
TRAINING (X_1)	Access to training	
	Yes	0.61
	No	0.39
EXTENSION (X_2)	Extension	
	Yes	0.19
	No	0.81
EXTE_CC (X_3)	Extension on climate change	
	Yes	0.70
	No	0.30

4.3. RESULTS AND DISCUSSION

4.3.1. Demographic and Socioeconomic Characteristics of the Sampled Farmers

The demographic and socioeconomic characteristics of the sampled farmers are presented in Tables 4.4 and 4.5. Table 4.4 displays continuous variables means and standard deviations, while Table 4.5 presents categorical variables and their corresponding proportions. Table 4.4 shows that the average age of smallholder farmers in the uMkhanyakude district was approximately 55.77 years at the time of the study, suggesting that older farmers dominate the smallholder farming sector. This finding aligns with expectations, as younger household members migrate to urban areas in search of employment, leaving behind an ageing farming population. Similar results have been observed in other studies focusing on smallholder farming (Maziya *et al*., 2020; Sinyolo *et al*., 2018; Hitayezu *et al*., 2017). This finding has implications for the future and sustainability of smallholder agriculture in the uMkhanyakude district since farming knowledge is not transferred to the youth. Without the transfer of knowledge and skills from older farmers to the youth, there is a risk of losing valuable agricultural expertise and traditions, which could hinder the long-term viability of smallholder agriculture in the district.

Table 4.4 indicates that household heads did not progress to secondary school on average. Approximately 23% of the smallholder farmers had no formal education (Table 4.4). However, this proportion of farmers with no formal education exceeds 4.8% for KZN (Stats SA, 2019).

Education is critical to enhance farmers' ability to obtain, analyse and process climatchange-related information (Onyeneke *et al*., 2018).

As shown in Table 4.4, households had moderate amounts of livestock units (TLU), household assets (TOTASSETV) and annual income (TOTAL_INCOME). Smallholder farmers indicated that they had access to an average of 1.31 ha of agricultural land (LAND_SIZE). The traditional leader (LANDALLOC) allotted most of the agricultural land to farmers. On average, each farming household has four adult equivalent members (H_ADULTS). Inheritance (LANDINHERIT) from relatives is the second largest source of household farming land. On average, farmers in the uMkhanyakude district had 17 years of farming experience, indicating a considerable wealth of farming knowledge.

Table 4.4: Description of Continuous Variables

Variable code	Variable description and measurement	Mean	Standard deviation
AGE	Age of household head (years)	55.77	12.36
EDUCAT	Years of schooling	7.14	4.74
LAND_SIZE	Land size in hectares (ha)	1.31	1.20
FARMING_EXPERIENCE	Number of years in farming	17.02	13.81
TARRED_ROAD	Distance to tarmac road (Km)	3.01	0.13
H_ADULTS	Number of adult equivalent members residing in the household (continuous)	4.25	3.76
TOT_ASSETV	Value of household assets (Rands)	95342.13	135639.7
TLU	Tropical Livestock Units	8.13	12.23
TOTAL_INCOME	Total annual income (Rands)	55674.49	32568.76

Further to the comparison of continuous variables, categorical variables were compared to get a better understanding of the sampled households. Table 4.5 shows that 28% of the sampled households were headed by males during the study, implying that smallholder farming in uMkhanyakude was dominated by females. This result tallies with findings in other studies (Sinyolo *et al.,* 2018; Murugani & Thamaga-Chitja, 2018; Maziya *et al*., 2017). Men migrate to cities for paying jobs, leaving their spouses in rural areas to engage in farming and take care of household members.

Table 4.5 shows that 19% of the farmers received extension services between August 2019 and August 2020. This implies that agricultural-related support was extremely limited in the study area. This finding aligns with the results reported in the General Household Survey, where it was reported that 13.6% of agriculturally active black households in the KZN province received agricultural support in 2017 (Stats SA, 2018).

More than half of the sampled farming households indicated that they had access to credit (CREDIT), training (TRAINING) and improved farming technologies (IMPROVEDTECHACC). The survey results also show that fewer farmers (35%) were members of farmer associations (FARMASSOC). Membership in farmer associations increases social capital in rural areas, and farmers with a solid social network could enjoy better access to resources and information on climate change (Debela *et al*., 2015).

Table 4.5: Description of Categorical Variables

Variable code	Variable description and measurement	Proportion
GENDER	Gender of household head (Male=1)	0.28
NOFORMAL_EDU	Household heads with no form of education (Yes=1)	0.23
LANDALLOC	Land allocated by traditional authority (Yes=1)	0.50
LANDINHERIT	Land inherited from family members (Yes=1)	0.33
FARM_ASSOC	Membership in farmers' association (Yes=1)	0.35
EXTENSION	Access to extension services (Yes=1)	0.19
CREDIT	Access to credit (Yes=1)	0.53
MARKET_ACCESS	Access to output markets (Yes=1)	0.62
TRAINING	Access to training (Yes=1)	0.55
IMPROVED_TECHACC	Access to improved farming technologies (Yes=1)	0.58
JOZINI	Jozini Local Municipality (Jozini=1)	0.53
UMHLABUYALINGANA	uMhlabuyalingana Local Municipality (uMhlabuyalingana=1)	0.47

4.3.2. Smallholder Farmers’ Perceptions of Climate Change

Table 4.6 summarises the perceptions of smallholder farmers on climate variables. Most farmers indicated that summer (80.25%) and winter (81.25%) rainfall has decreased from 1999-2019. The majority (76.75%) of the farmers indicated that winter and summer temperatures had increased. However, farmers perceived the incidence of floods (65.25%) to have decreased in the 20-year period. In contrast, the majority of farmers (71%) in the uMkhanyakude district reported an increase in the incidence of drought. These perceptions of climate change among farmers align with the observed trends in rainfall and temperature in meteorological records. Similar findings regarding farmers' perceptions of climate change have been reported in studies conducted in South Africa (Shisanya & Mafongoya, 2017; Hitayezu *et al*., 2017; Ubisi *et al*., 2017); Ethiopia (Asrat & Simane, 2018) and Zimbabwe (Moyo *et al*., 2012). However, it is worth noting that farmers were required to recall knowledge on climate change over a 20-year period. Farmers may have put emphasises on recent climatic events rather than considering the whole 20-year period.

Table 4.6: Proportion of Farmers Who Noticed Long-Term Changes in Climate Variables

Noticed changes in the past 20 years	Increased	Decreased	Remained the same	I do not know
Summer season rainfall	14	80.25	4.25	1.25
Winter rainfall	10.50	81.25	6.75	1.00
Length of summer season rainfall	13.25	78.00	6.50	1.75
Summer temperatures	76.75	19.25	2.50	1.50
Winter temperatures	42.25	47.50	9.25	1.00
Frequency of drought	71	19.75	7.00	1.75
Frequency of floods	12.25	65.25	12.75	9.25

Table 4.7 compares farmers’ climate events recollection against meteorological records (as illustrated in Chapter 3) for uMkhanyakude district. Farmers’ recollections of extreme weather events did match meteorological records. Table 4.7 indicates that the study area was dominated by drought in the 20-year period. These findings show that uMkhanyakude district is getting drier. The results of this study align with the findings of Shisanya and Mafongoya (2017), who conducted a similar assessment of climate change perceptions in the uMzinyathi district of KwaZulu-Natal and found that drought was prevalent in the area. The implication is that there

could be less water for farming, leading to food and nutrition insecurity among smallholder farmers in the district.

Table 4.7: Farmers' Perceptions of Extreme Weather Events in uMkhanyakude District

Year	Farmers' observations	Evidence from meteorological records
2000	Floods	Rainfall for the year 2000 was above average (836 mm above average)
2002-2003	Drought	2002 and 2003 received below-average rainfall, 332 mm and 353 mm, respectively.
2005	Drought	2005 received slightly below-average rainfall (492 mm), with January (144.3 mm) and November (109.1 mm) receiving the most rainfall
2008	Drought	2008 recorded below-average rainfall (415 mm), with November (81.4 mm) and December (86 mm) receiving the most rain.
2010-2011	Drought	The years 2010 and 2011 received below-average rainfall, 476 mm and 473, respectively
2014-2016	Severe drought	2014-2016 were dry years receiving below-average rainfall.

Table 4.8 presents the results of the principal component analysis (PCA) employed to identify the dominant climate change perceptions in the sample. Using the Kaiser criterion (Field, 2005), five PCs with eigenvalues greater than one were retained, explaining 81.78% of the variation in the selected variables. A sufficient proportion of the variables is present if less than five or six of the PCs describe 70-80% of the variation in the variables (Mandleni & Anim, 2011). The scree graph (Figure 4.1) illustrates the relationship between PC numbers and eigenvalues. The x-axis represents the PC numbers, while the y-axis represents the eigenvalues. The PCs retained for analysis are those on the slope of the graph before the decrease in eigenvalues start to level off.

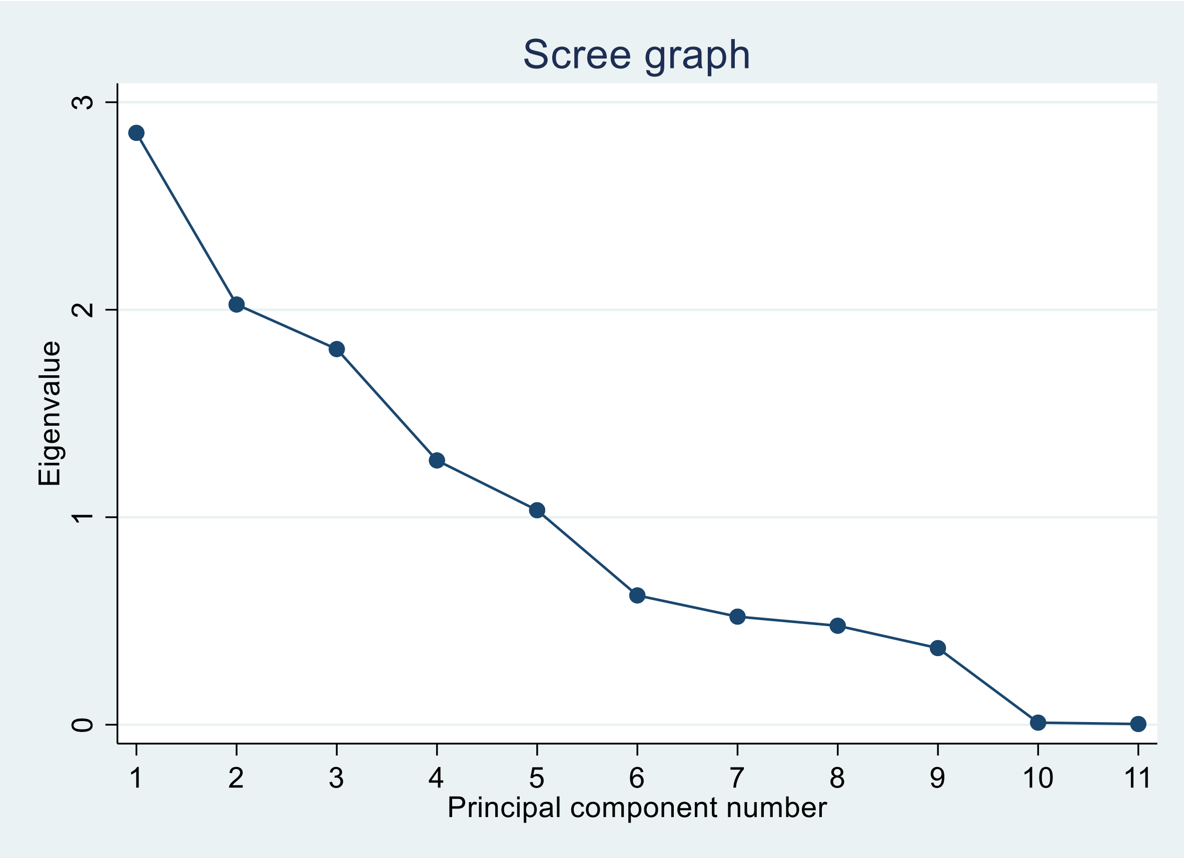

Figure 4.1: Scree Graph of Principal Components and Eigenvalues

The first principal component (PC_1) has an eigenvalue of 2.852 and contributed 25.93% to the variation in the data. The dominant perceptions under PC_1 were drought and floods (natural disasters). From an agro-climatic perspective, drought and floods are adverse conditions that limit agricultural productivity in rainfed agricultural systems. The second principal component (PC_2) has an eigenvalue of 2.025 and contributed 18.41% to the data variation. The dominant perceptions related to PC_2 are training and access to extension services. Access to training and extension services is valuable for farmers as it provides them with the necessary information and knowledge. The third principal component (PC_3) has an eigenvalue of 1.811, explaining 16.46% of the variation in the data. Under PC_3, the dominant perceptions are decreasing crop yields and loss of assets. These perceptions indicate the negative impacts of climate change on agricultural production and household valuables, such as houses, resulting from climatic disasters like storms and tropical cyclones.

The fourth principal component (PC_4) has an eigenvalue of 1.274, contributing to 11.58% of the variation in the data. The dominant perceptions associated with PC_4 are long-term changes in temperature and rainfall. In the uMkhanyakude district, these changes, such as increasing temperatures and decreasing rainfall, negatively impact on crop and livestock farming, as farmers rely on rainfed agricultural systems. The fifth principal component (PC_5), with an eigenvalue of 1.034, explains 9.40% of the variation in the data. The dominant loadings in PC_5 indicate that farmers who perceived poor livestock production also perceived the need for extension services on climate change. Poor livestock productivity resulting from unfavourable climatic conditions, such as drought, is a significant concern, as many rural farmers depend on livestock. Moreover, access to climate change information through extension services can play a role in mitigating the negative impact of climate change on livestock productivity.

The principal component analysis of farmers' perceptions of climate change indicates that farmers can recall changes in their local climate. Farmers were effectively classified using a single index of climate change perception by employing PCs in this study. This approach has comprehensively understood farmers' collective perception of climate change.

Table 4.8: Principal Components Retained in the Analysis

Variables	**Principal Components**				
	PC_1	**PC_2**	**PC_3**	**PC_4**	**PC_5**
TRAINING (X_1)	-0.0414	**0.6532**	-0.2669	-0.0049	-0.0128
EXTENSION (X_2)	-0.0393	**0.6527**	-0.2688	-0.0068	-0.0132
EXTE_CC (X_3)	-0.0212	-0.0859	-0.2561	0.3582	**0.7221**
TEMPERATURE_CHANGE (X_4)	-0.1945	0.0762	0.2089	**0.6660**	-0.0815
RAINFALL_CHANGE (X_5)	-0.3208	0.0422	0.1556	**0.4981**	-0.2109
DROUGHT_FREQ (X_6)	**0.5488**	0.0913	0.1371	0.1316	0.0468
FLOODS_FREQ (X_7)	**0.5441**	0.1003	0.1603	0.1274	0.0305
STRONG_WINDS (X_8)	0.4698	0.0715	0.0991	0.2400	-0.0419
POOR_LIVEPRO (X_9)	-0.1224	0.1485	0.3779	-0.2463	**0.5394**
DECREASE_CROPY (X_{10})	-0.0526	0.2027	**0.5130**	-0.1662	-0.2391
LOSS_ASSETS (X_{11})	-0.1411	0.2137	**0.5126**	-0.0233	0.2722
Eigen value	2.852	2.025	1.811	1.274	1.034
Variance (%)	25.93	18.41	16.46	11.58	9.40
Cumulative %	25.93	44.43	60.80	72.38	81.78

4.4. SUMMARY

The objective of this chapter was to evaluate the perceptions of smallholder farmers on climate change in the uMkhanyakude district. Descriptive statistics indicated that women dominated smallholder farming, and older people constituted the majority of smallholder farmers. Generally, farmers perceived that summer season rainfall had decreased while summer season temperatures had increased. Further analysis using the principal component technique revealed that dominant climate change perceptions could be classified into a) natural disasters (drought and floods); b) institutional support (training and access to extension services); c) decrease in crop yields and loss of assets; d) changes in temperature and rainfall and e) extension on climate change (access to information) and poor livestock production. These findings highlight the diversity of farmers' perceptions of climate change. The significant proportion of smallholder farmers who did not receive extension services between 2019 and 2020 emphasises the need for improved agricultural support in rural areas.

CHAPTER 5: SOCIOECONOMIC DETERMINANTS OF CLIMATE CHANGE PERCEPTIONS AMONG SMALLHOLDER FARMERS

5.1. INTRODUCTION

Smallholder farmers in developing countries are widely recognised as the most vulnerable to the impacts of climate change and variability due to their dependence on climate-sensitive agricultural systems (Foguesatto & Machado, 2020; Mandleni & Anim, 2011; Maponya, Mpandeli & Oduniyi, 2013). The IPCC (2012) projected increased frequency and intensity of extreme weather events, such as droughts and floods. As a result, the food insecurity situation in Africa is expected to worsen due to climate change (Ubisi *et al*., 2017). The limited adaptive capacity, low technology adoption, restricted access to climate change information, and marginalised locations of smallholder farmers contribute to their heightened vulnerability to climate change (Harvey *et al*., 2014; Thamaga-Chitja & Morojele, 2014).

Several studies (Hitayezu *et al*., 2017; Oduniyi *et al*., 2018; Mandleni & Anim, 2011; Foguesatto & Machado, 2020) have demonstrated that climate change perceptions are influenced by various factors such as socioeconomic, socio-psychological, demographic, cultural and institutional factors. For instance, Oduniyi *et al*. (2018) conducted a study in the North West province of South Africa. They found that factors such as the size of land holding, education level, access to information on climate change, support services related to climate change, and extension services played a role in shaping climate change awareness. In Zimbabwe, Mudombi *et al*. (2014) found that factors such as access to radio and newspapers, mobile phone ownership, extension services and participation in farmer associations positively impacted climate change perception.

To ensure successful adaptation to climate change, smallholder farmers require access to relevant information and knowledge about various aspects of climate change, including its causes and strategies for adaptation. Similarly, policymakers and stakeholders involved in climate risk communication must understand the underlying factors shaping farmers' perceptions of climate change. Against this backdrop, this chapter explores the socioeconomic factors that influence climate change perceptions among smallholder farmers in the uMkhanyakude district of the KwaZulu-Natal province in South Africa. The subsequent sections of this chapter are structured as follows: Section 5.2 outlines the empirical model employed to analyse climate change perceptions, along with a description of the variables incorporated in the model. Section 5.3 presents the results and discussion. Lastly, section 5.4 summarises the chapter.

5.2. EMPIRICAL MODEL

5.2.1. Dependent Variable and Model Specification

Farmers' perception of climate change is modelled as a binary response variable, taking a value of 1 if the farmer perceives climate change and 0 otherwise. Binary logistic regression models are commonly used when the dependent variable is dichotomous. Previous studies (Oduniyi *et al*., 2018; Foguesatto & Machado, 2020; Mustafa *et al*., 2019; Hasan & Akhter, 2011) have employed binary logistic regression models to examine the factors influencing climate change perceptions among smallholder farmers. This study also used a binary logit model to assess the socioeconomic determinants of climate change perceptions among smallholder farmers. According to Hasan and Akhter (2011), the logistic model can be expressed as follows:

$$\text{In}\left[\frac{P}{1-P}\right]=\beta_0+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\beta_4 X_4+\beta_5 X_5+\varepsilon$$

Where $P/(1-P)$ is the likelihood or odds ratio; P is the probability that a farmer perceives climate change; $1-P$ is the probability that a farmer does not perceive climate change; β_0 is the constant term, X_1, X_2….X_5 denotes the set of explanatory variables, β_0, β_1, β_2… β_5 are the parameters of the model and are estimated using the maximum likelihood method, and ε is the error term. According to Tesfahunegn *et al*. (2016), the dependent variable is increased when the odds ratio is greater than 1, there is no relationship if the odds ratio is equal to 1 and an odds ratio that is less than 1 indicates a negative relationship. A major advantage of using a binary logistic model is that it provides the coefficient size and the direction of the predictor. However, it is limited in that it requires no multicollinearity between the independent variables. To counter this problem, the independent variables were tested for multicollinearity and related variables were removed from the model.

A stepwise logistic regression was further used to refine the model. In the first step, each independent variable was regressed against the dependent variable to determine the *t* values. In the second step, the independent variables were regressed in chronological order starting with the variable with the highest t value. Out of the 13 initial variables considered based on a review of the literature, five were retained in the final model.

5.2.2. Independent Variables and Working Hypothesis

The independent variables for the binary logistic model included demographic characteristics of farmers, farm characteristics and institutional factors. They were selected based on the literature on climate change perception.

The age of the household head (AGE) is a demographic variable representing the respondent's social values and individual attitudes towards the world regarding climate change. Farmers' ability to perceive climate change is influenced by personal experiences that increase with advancement in age (Debela *et al.*, 2015). Age is also considered a proxy for farming experience. Therefore, advancement in age is expected to have a positive effect on climate change perception.

The household head level of education (EDUCAT) is both a cognitive and experiential variable in the logistic model. Gaurav and Singh (2012) argue that education increases farmers' cognitive ability to read, analyse and process climate related information, thus increasing their probability of perceiving climate change. In the model, the level of education of the household head is expected to have either a positive effect on climate change perception.

Membership in farmers' association (FARM_ASSOC) in the logistic model is an institutional variable that represents social capital. Behavioural studies (i.e., Hagen, 2013; Hitayezu *et al.*, 2017) have shown that networks can be a source of environmental information hence farmers who have more networks are likely to perceive climate change. The variable is expected to have a positive effect on climate change perception.

Landholding (LAND_SIZE) is an experiential variable that represents sensitivity to climate change and variability. Small farms are characterised by similar bio-geophysical properties (i.e., soil fertility) that amplify vulnerability to climate change (Hitayezu, 2015). Therefore, farmers with small farm sizes are more sensitive to climate change and are expected to perceive climate change.

Access to irrigation (ACCESS_IRRIG) measured as the distance to the nearest river or dam represents resilience to climate change through irrigation as a coping mechanism (Gbetibouo et al., 2010). Farmers who irrigate their crops have a degree of control over the negative effects of climate change thus decreasing their probability of perceiving climate change (Deressa et al., 2010). Therefore, proximity to a river or dam is expected to have a negative effect on climate change perception.

The variable for adult equivalents (H_ADULTS) represents the availability of labour in the household. Farmers were asked to count the number of people above 18 years residing in the household who assist in farming. Cutler and Katz (1992) introduced an approach that measures adult equivalents. The function can be computed as follows:

Adult equivalent= $(Y+ \alpha B)\beta$

Y is the number of adults involved in farming, B is the number of children in the household, α is an index that adjusts for age differences and is set at less than 1 and β is a constant that adjusts for economies of scale between adult and children and is also set at less than 1. Studies (i.e., Cutler and Katz, 1992; Streak et al., 2009) that have employed this approach in South Africa fix α at 0.5 and β at 0.9. A household with more adults tends to have a variety of skills, knowledge and extensive social capital, enhancing the probability of perceiving climate change through sharing of information (Deressa et al., 2010). Therefore, this variable is expected to positively affect climate change perception. Table 5.1 presents the logistic model variables, including socioeconomic, demographic, and farm characteristics, their definition and expected effect on farmers' perception of climate change.

Table 5.1: Variables Used in the Binary Logistic Model

Variable code	**Variable name**	**Variable description and measurement**	**Expected sign**
CC_PERCEPTION	Climate change perception	1= the climate is changing, and 0 otherwise	
AGE	Age	Age of household head in years (continuous)	+
EDUCAT	Education	Years of schooling (continuous)	+
LAND_SIZE	Land size	Land size in hectares (continuous)	-
H_ADULTS	Adult equivalents	Factor representing household labour endowment (continuous)	+
FARM-ASSOC	Membership in farmers associations	1 if the respondent is a member in a farmers' organisation and 0 otherwise (dummy)	+
ACCESS_IRRIG	Access to irrigation infrastructure	1 if the respondent has access to irrigation infrastructure and 0 otherwise (dummy)	-

5.3. RESULTS AND DISCUSSION

5.3.1. Demographic and Socioeconomic Characteristics of the Farmers

The sample was disaggregated by climate change perception. A comparison of means for continuous variables using T-test is presented in Table 5.2. Overall, the T-test results reveal significant differences in the characteristics of climate change perceivers and non-perceivers. As indicated in Table 5.2, 382 (95.5%) farmers perceived climate change. This implies that most farmers in the uMkhanyakude district were aware of climate change during the study period. This proportion of climate change perceivers is slightly higher than that of other studies conducted in KwaZulu-Natal (Shisanya & Mafongoya, 2017; Hitayezu *et al*., 2017). However, similar to other studies conducted in other parts of Africa (Debela *et al.,* 2015).

A comparison of means for independent variables indicates significant differences in the mean age of perceivers and non-perceivers. On average, non-perceivers were 44.41 years old, while perceivers were approximately ten years older (56.27). This indicates that with advancement in age, farmers gain farming experience, which increases their probability of perceiving climate change.

On average, a perceivers' household had four adult equivalent members (H_ADULTS), while a non-perceiver' household had approximately two adult equivalent members. The literature suggests that households with a larger pool of adult equivalents are less likely to perceive climate change because some members may be involved in off-farm employment, which decreases the households' susceptibility to climate change (Hitayezu, 2015). This result implies that households with high adult equivalent members in the study area also engage in agriculture because of limited job opportunities. Household members use their social capital, skills, and knowledge, which comes as they age, increasing their probability of perceiving climate change.

The mean levels of land holding (LAND_SIZE) in the sample differed between perceivers and non-perceivers. On average, perceivers owned 1.34 hectares, while non-perceivers owned 0.63 hectares. Similar findings on land holding between perceivers and non-perceivers have been reported in KwaZulu-Natal (Hitayezu *et al*., 2017).

The results revealed differences in access to irrigation (ACCESS_IRRIG) between the two groups. On average, farmers who perceived climate change travelled approximately 3.54 km to reach the nearest river or dam. In comparison, non-perceivers travelled almost twice the distance (7.29 km) travelled by a perceiver to reach the nearest river or dam. These findings contrast with existing literature on farmers' climate change perception. Typically, farmers residing closer to a water source have easier access to irrigation, reducing their vulnerability to climate change's adverse effects and decreasing their likelihood of perceiving climate change (Ndambiri, Ritho & Mbogoh, 2013). However, in the context of the uMkhanyakude district, the contrasting result may be attributed to the prevailing dry conditions. Dams and perennial rivers in the area have dried up due to prolonged heat, which could have been experienced by farmers residing closer to these water sources. As a result, these farmers may have a higher probability of perceiving climate change due to first-hand observations of drying rivers and dams nearby.

Involvement in farmers' associations was significantly different among farmers in the two groups, with perceivers recording a higher proportion (33%) compared to non-perceivers (30%). The plausible explanation for this result is that social networks such as farmers' associations play an important role in influencing climate change perception.

Table 5.2: Summary Statistics of Continuous Variables According to Climate Change Perceptions

Variables	Pooled sample (N=400)		Perceivers (N=382)		Non-perceivers (N=18)		T-test/ X^2
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	
Age	55.77	12.36	56.27	11.94	44.41	16.19	-3.94***
H_ADULTS	4.25	3.76	4.33	3.82	2.47	1.33	-2.00 **
LAND_SIZE (ha)	1.31	1.20	1.34	1.21	0.63	0.50	-2.40**
ACCESS_IRRIG	3.70	2.57	3.54	2.28	7.29	5.07	6.16***
EDUCATION	8.49	3.85	8.53	3.81	7.41	4.62	-1.17
FARM_ASSOC	0.35	-	0.33	-	0.3	-	10.92***

Note: ** and *** means significant at 5% and 1%, respectively

5.3.2. Determinants of Climate Change Perceptions

The Variance Inflation Factor (VIF) was used to test for multicollinearity between independent variables. A value of less than ten is generally considered acceptable to indicate the absence of significant multicollinearity (Gujarati, 2004). With a mean VIF of 1.06, Table 5.3 shows that multicollinearity was not a problem between the independent variables.

Table 5.3: Multicollinearity Test Between Independent Variables

Variable	**Variance Inflation Factor (VIF)**	**Multicollinearity Tolerance**
AGE	1.06	0.939
EDUCAT	1.04	0.964
LAND_SIZE	1.09	0.917
H_ADULTS	1.05	0.951
FARM_ASSOC	1.06	0.943
ACCESS_IRRIG	1.03	0.966
MEAN VIF	1.06	

On learning that multicollinearity was not an issue, a binary logistic regression model was estimated to determine the socioeconomic factors influencing climate change perception. Table 5.4 presents the results of the binary logistic model. The model is highly significant ($p=0.0000$), indicating that the model is a good fit. The sign of the logistic model's coefficient shows the independent variable's direction on the dependent variable. A positive sign in the coefficient implies that a unit increase in the independent variable will increase the likelihood of a farmer perceiving climate change, with all other coefficients held constant. Conversely, a negative sign in the coefficient implies a decrease in the log odds of a farmer perceiving climate change, with all other coefficients held constant.

The coefficient for age (AGE) of the household head is statistically significant ($p<0.01$) and positively related to climate change perception, indicating that older farmers are more likely to perceive climate change compared to younger farmers. In this study, age was used as a proxy for farming experience. This finding was expected as farmers' ability to notice climatic changes is influenced by their knowledge and personal experiences, which they accumulate with advancement in age (Mudombi *et al*., 2014; Debela *et al*., 2015). These results are consistent with findings from other studies conducted in South Africa (Maponya *et al*., 2013; Hitayezu *et* *al*., 2017) and in various regions of Africa (Deressa *et al*., 2011; Asrat *et al*., 2018; Debela *et al*., 2015).

The results in Table 5.4 also show that the coefficient for involvement in farmers' associations (FARM_ASSOC) is significant ($p<0.05$) and positively related to climate change perception. The odds of perceiving climate change are 4.84 higher among smallholder farmers in a farmers' association. This result underscores the role of social networks in inducing climate change perception. In farmers' associations, smallholder farmers share information, experiences, and knowledge about climate change through participatory learning (Elia, 2017). This result corroborates other studies conducted in Zimbabwe (Mudombi *et al*., 2014) and Tanzania (Elia, 2017).

Table 5.4: Determinants of Climate Change Perception, Logit Results

Variable	**Odds Ratio**	**SE**	**P>|z|**
AGE	1.099	0.027	0.000***
EDUCAT	1.158	0.078	0.028**
LAND_SIZE	5.406	3.945	0.021**
H_ADULTS	1.876	0.517	0.022**
FARM_ASSOC	0.234	0.154	0.027**
ACCESS_IRRIG	1.778	0.058	0.001***
Constant	0.022	0.038	0.027**
LR chi2(12)	68.46		
Prob > chi2	0.0000***		
Pseudo R^2	0.4867		
Number of observations	400		
Mean VIF	1.04		

Note: ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Having attained higher levels of education increases the likelihood of perceiving climate change by 1.158 odds. Higher levels of education increase awareness of climate change as an issue of immediate concern. Farmers who attained education can receive, process and recognize changes in the environment and understand information relating to climate change (Amir *et al*., 2020; Kimani and Bhardwaj, 2015; Mutunga *et al*., 2018). Empirical studies have shown that the level of education correlates to the level of knowledge and the simplicity of making sound decisions (Jiri *et al*., 2015; Anley *et al*., 2007). In the same vein, higher levels of education coupled with farming experience should improve farmers' perceptions of climate change. Other studies (i.e., Ndambiri *et al*., 2012) conducted across African farming systems have also shown that education plays an important role in influencing farmers' perception of climate change.

The results of the study show a positive and significant relationship between adult equivalents (H_ADULTS) and climate change perception. An increase of one adult equivalent increases climate change perception by 1.876 odds. As posited by Ojo and Baiyegunhi (2021) and Hitayezu *et al*., (2017), an increase in adult equivalent members in a household increases the probability of perceiving environmental changes as a result of the negative impacts of climate change. This possibly occurs because more members of the household are exposed to climate change information through different platforms such as media.

The results show a positive and significant relationship between land size (LAND_SIZE) and climate change perception. A one hectare increase in landholding increases climate change perception by 5.406 odds. A plausible explanation for this result is the fact that the perception of climate change takes place faster on larger farm sizes compared to smaller farm sizes (Ojo and Baiyegunhi, 2021). This result is in consonance with the findings from Bryan *et al*. (2013) and Thinda *et al*. (2020).

The coefficient of access to irrigation (ACCESS_IRRIG) is statistically significant and positively related to climate change perception. Access to irrigation increases climate change perception by 1.778 odds. The plausible explanation for this result may be traced to the fact that farmers have to irrigate more often due to higher temperatures and inadequate rainfall and this triggers the perception of climate change.

5.4. SUMMARY

The objective of this chapter was to examine the socioeconomic factors that influence farmers' perceptions of climate change. Farmers perceptions determine their response to the adverse impacts of climate change. The descriptive analysis revealed that most sampled farmers (95.5%) perceived a difference in the climate, with females constituting the majority (69%) of the perceivers. Perceivers were, on average, ten years older than non-perceivers and had more adult equivalents in their households. Perceivers had larger plot sizes compared to non-perceivers.

The results of the binary logistic regression model indicated that access to irrigation, education level, land size, involvement in farmer organizations and adult equivalents play an essential role in influencing farmers' perception on climate change. These findings highlight the importance of institutional arrangements, such as extension services and farmers' associations, in disseminating climate change information and shaping farmers' perceptions of climate change.

CHAPTER 6: THE PERCEIVED IMPACT OF CLIMATE CHANGE ON THE LIVELIHOODS OF SMALLHOLDER FARMERS

6.1. INTRODUCTION

Climate change is a threat to both the biophysical and socioeconomic environment. The impacts of climate change pose significant challenges to critical economic development sectors, including agriculture, fisheries, forestry, tourism, manufacturing, and health (Tiyo, Orach-Meza & Edroma, 2015; Ubisi *et al*., 2017). The adverse effects of climate change will hamper global efforts to achieve the 2030 Agenda for Sustainable Development, especially goals aimed at eradicating poverty and hunger (SDG 1 and SDG 2).

The agricultural sector plays a vital role in the lives of smallholder farmers and is particularly susceptible to the impacts of climate change (Simane, Zaitchik & Folz, 2014). Estimates suggest that 70% of the population on the African continent depends on rainfed agriculture and ecosystem services for their livelihood (Connolly-Boutin & Smit, 2016; Shiferaw *et al*., 2014). The effects of climate change on the agricultural sectors across the African continent will vary (Alemu & Mengistu, 2019). Central, western, and southern African regions are expected to face more frequent hot and dry seasons (Ubisi *et al*., 2017). In addition, farmers in this region face many risks, including market shocks, pests and diseases, conflicts, poor governance, and economic instability (Harvey *et al*., 2014). These shocks face smallholder farmers whose vulnerability is partly affected by poverty and weak institutional arrangements and have the potential to erode livelihoods (Connolly-Boutin & Smit, 2016).

The adverse effects of climate change manifest through alterations in rainfall patterns and rising temperatures, leading to prolonged droughts and reduced crop and livestock productivity (Ubisi *et al*., 2017). Sub-Saharan Africa is expected to experience increased flooding incidents in low-lying areas, while dry conditions will accelerate desertification (IPCC, 2014; Connolly-Boutin & Smit, 2016). Gezie (2019) asserts that the negative impacts of climate change will result in the loss of livelihoods for smallholder farmers in countries where agriculture is the primary source of income. Consequently, these detrimental impacts pose significant risks to smallholder farmers' food security and well-being, who possess limited adaptive capacity due to resource constraints (Harvey *et al*., 2014). Moreover, the challenges smallholder farmers face is compounded by their marginal location, restricted access to climate change information and low adoption rates of technological advancements (Thamaga-Chitja & Morojele, 2014).

As a result, farmers in such circumstances tend to reactively adapt, which is insufficient to mitigate the losses caused by climate change (Tripathi & Mishra, 2017).

According to the IPCC (2018), agricultural losses in Southern Africa due to climate change are projected to range between 0.4% and 1.3% of the region's Gross Domestic Product (GDP) by 2100. This prediction is supported by the FAO (2016), which states that global maize production is expected to decline by up to 10% by 2050, with a more significant drop of 20% projected for Africa. In the context of South Africa, Juana, Kahaka and Okurut (2013) demonstrates that changes in rainfall patterns caused by climate change could result in a 12% reduction in agricultural output. This decline in agricultural productivity will lead to higher food prices, adversely affecting smallholder farmers' food security.

This chapter aims to investigate the perceived impact of climate change on the livelihoods of farming households in the uMkhanyakude district of KwaZulu-Natal. Understanding the adverse effects of climate change on the livelihoods of rural people is crucial in designing appropriate climate change policies. The subsequent sections are structured as follows: Section two explores the data analytical techniques utilised in this study. Section three presents the results and discussion, and the final section concludes the chapter.

6.2. ANALYTICAL METHODS

This section discusses the analytical methods that were adopted in this chapter. These include a description of the thematic analysis and the Sustainable Livelihood Framework.

6.2.1. Data Analysis

Thematic analysis was used to analyse qualitative data. According to Byrne (2022), thematic analysis is a method for identifying and analysing patterns of meaning in a data set. It shows the dominant themes that best describe the subject under investigation. According to Gumede, Maziya and Chiumbu (2018), thematic analysis involves interpretation, impressionistic and textual analysis of qualitative data. The thematic approach is subjective and considers the respondent's lived experiences and how they infer meaning on the subject under investigation. The transcriptions of the qualitative data from the focus group discussions (FGDs) were imported into ATLAS.ti for analysis. ATLAS.ti is a software programme commonly used for qualitative data analysis, facilitating the organisation, coding, and exploring textual data.

The textual data were read repeatedly to get a deeper insight into the transcripts. Labels that appeared more than once were coded, and similar codes were organised into categories. Each category was then defined, and four main themes emerged from the data: cropping patterns, livestock production, wild plants and animals and water availability. The potential setback when using thematic analysis arises when there is a misunderstanding of the data due to loss of information during translation, and this results in findings that are not coherent with the data (Gumede *et al.,* 2018). Constant interaction with the respondents, debriefing and continuous observations are some of the mechanisms used to improve the quality of the data (Nowell, Norris, White & Moules, 2017).

The quantitative data from the survey were coded and analysed using STATA Version 15. Descriptive statistics, such as frequencies and percentages, were computed to analyse the data. The findings were then presented in tables and pie charts to provide a clear visual representation of the results.

6.2.2. Conceptual Framework

Over the last three decades, the sustainable livelihoods approach in various forms has influenced development research and practice (Liu *et al.,* 2018). Multiple organisations, including the Department for International Development (DFID), United Nations Development Program (UNDP) and CARE International (CARE), have embraced the sustainable livelihood approach in their efforts to alleviate poverty (Quandt, 2018). The DFID, for instance, has utilised this framework as a planning tool for development initiatives and assessing the effectiveness of ongoing programmes, aiming to identify opportunities for supporting the livelihoods of agricultural communities (DFID, 1999).

The Sustainable Livelihood Framework (SLF) is based on the notion that individuals create diverse and complex livelihood portfolios undermined by climatic, political, and economic uncertainty (Clay, 2017). Smallholder farmers rely on various capital assets to achieve their desired livelihood outcomes (Figure 6.1). These assets encompass human, physical, natural, social, and financial resources. Livelihood assets, also known as capital assets, represent the strengths of smallholder farmers, enabling them to engage in a range of activities to attain their livelihood objectives, known as livelihood strategies. Livelihood strategies are dynamic processes that involve decision-making, and actions aligned with the aspirations of smallholder farmers over time (Muringai, Naidoo & Mafongoya, 2020). The external environment, which encompasses factors such as patterns, seasonality, and shocks that individuals face but has limited control over, is referred to as the vulnerability context within the SLF (Quandt, 2018). In this study, the SLF was employed to identify the livelihood strategies of smallholder farmers, assess their household capital assets, and examine their livelihood outcomes. This study uses the SLF to evaluate farmers' perceived effect of climate change (i.e., rainfall patterns, drought and floods) on their livelihood assets.

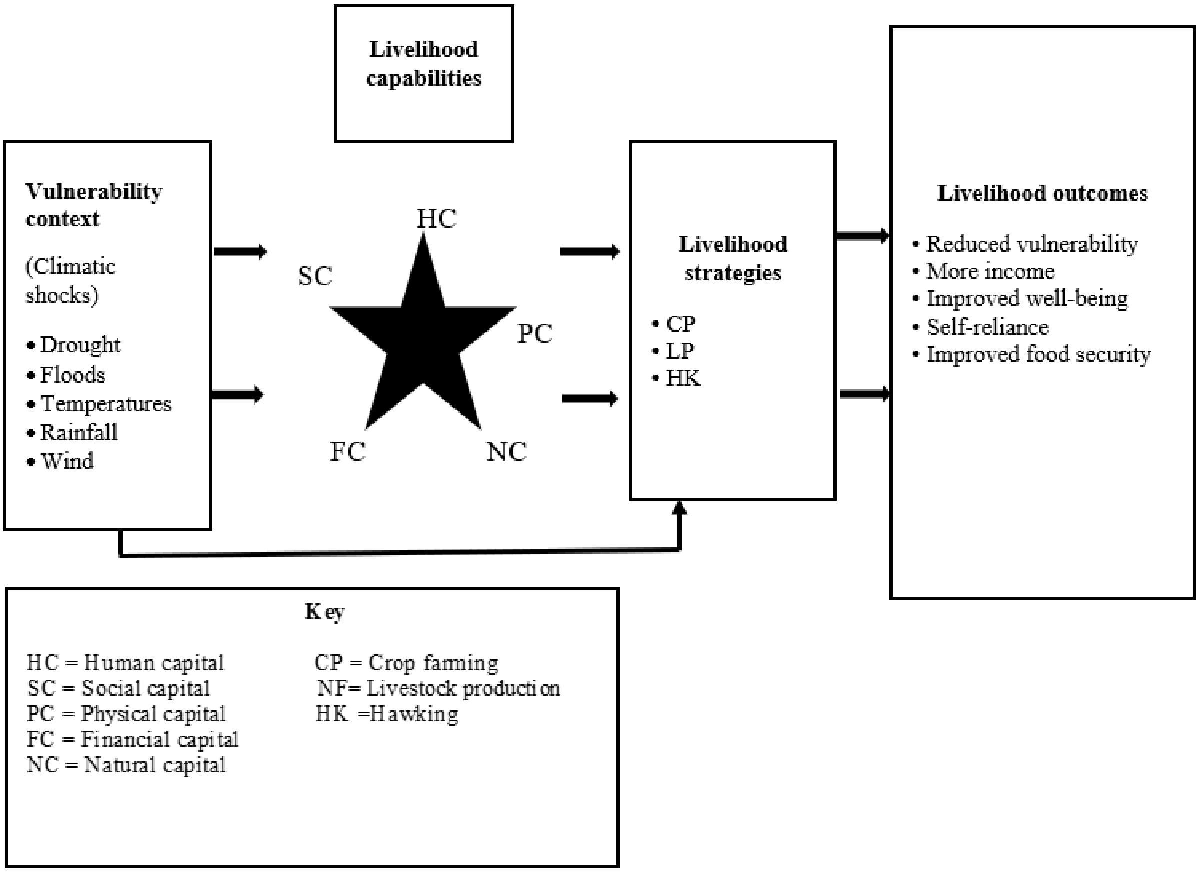

Figure 6.1: The Sustainable Livelihood Framework

Source: Adapted from the Department for International Development (DFID, 1999)

6.3. RESULTS AND DISCUSSION

The subsequent sections of this chapter provide a comprehensive presentation and discussion of the findings. These sections elaborate on the livelihood strategies adopted by smallholder farmers, the impact of climate change on their capital assets, and the implications of climate change on their livelihood outcomes.

6.3.1. Livelihood Strategies in the uMkhanyakude District

According to Mbatha, Mnguni and Mubecau (2021), livelihood strategies comprise a combination of activities farmers undertake to achieve their livelihood outcomes (income or food security). Table 6.1 presents the common livelihood strategies in the uMkhanyakude district. The results in Table 6.1 shows that crop production, livestock production and hawking are the common livelihood strategies in the uMkhanyakude district. Crop and livestock production were identified as the primary livelihood strategies employed in the study area. These findings are corroborated by the uMkhanyakude district Integrated Development Plan (IDP). It is reported that approximately 95% of households in the district rely on agriculture as a means of sustenance (uMkhanyakude District Municipality, 2019). The prevalence of such livelihood strategies suggests that a significant portion of households in the district is susceptible to the impacts of climate change, including shifts in temperature and rainfall patterns, given their dependence on rainfed agriculture.

Table 6.1: Livelihood Strategies in the uMkhanyakude District

Livelihood strategy	Number of households	Proportion (%)
Crop production	220	55
Livestock production	155	39
Hawking	25	6
Total	**400**	**100**

6.3.2. The Effect of Climate Change on Capital Assets

Household livelihood assets serve as a foundation for households to develop and implement strategies to improve their livelihood outcomes (Muringai *et al*., 2020). Households' capital assets include human, physical, financial, and social assets. Table 6.2 shows that households had an array of human assets.

6.3.2.1. Human Assets

The findings indicate that women are likely to be vulnerable to the negative effects of climate change than their male counterparts. Within the sample of smallholder farmers, women constitute the majority, accounting for 72% of participants. This finding aligns with the study conducted by Tamako and Thamaga-Chitja (2017), which also observed women as the primary participants in smallholder farming. This suggests that women are particularly susceptible to the adverse effects of climate change due to their reliance on agriculture for their livelihoods.

The findings also indicate that, on average, smallholder farmers are 55.77 years old and have 17 years of farming experience, implying that more senior people dominate smallholder farming. On average, each household has four adult equivalent members who assist in farming. Households with a sizeable group of working-age family members possess a greater labour

capacity for agricultural production. Such labour could be used to diversify household income by venturing into off-farm activities/employment that may not be affected by climate change.
On average, household heads in the study areas had attained 7.14 years of schooling, implying that most farmers did not progress to secondary education. Education is critical in achieving higher livelihood outcomes as it provides opportunities for farmers to engage in off-farm activities, thus diversifying their climate-sensitive agricultural-based livelihoods. Furthermore, education enhances farmers' ability to read and analyse climate change information, which can assist them in adapting and achieving better livelihood outcomes (Saroar & Routray, 2012).
Approximately 55% of the smallholder farmers reported receiving agricultural training. Farmers mentioned that training workshops focused on topics such as conservation agriculture and climate change adaptation, and they had effectively applied the knowledge in their farming practices. Training programmes improve agricultural skills, and farmers who have received training on climate change are more likely to implement adaptation strategies, thereby increasing agricultural productivity. Non-governmental organisations were the primary providers of such training. Other studies (Thinda *et al*., 2020; Aryal *et al*., 2021) have also found a positive relationship between agricultural training and climate change adaptation.
In the focus group discussions, farmers reported that temperature changes have negatively affected their productivity. High summer temperatures have forced farmers to reduce work hours in the morning and this has a negative impact on the size of land that they can work on. Over the years, farmers highlighted that there has been an increase in the incidence of violent storms during the summer season. These violent storms are often accompanied by lightning strikes which results in deaths of older family members. In turn, the loss of family members negatively impacts on farming activities.

6.3.2.2. Physical Assets

According to Serrat (2017), physical assets are capital goods households use to construct and contrive a livelihood. Such assets can be public goods (i.e., roads and water infrastructure) or private goods (i.e., tractors, implements and houses). Farmers in the two study areas identified homes, farm implements and access to transport as important physical assets needed to achieve livelihood outcomes. Table 6.2 shows that households are located 3.01 km from a tarmac road. This indicates that households' proximity to markets and other institutions (such as government departments) might play a role in supporting smallholder farming. On average, each household's combined value of assets is R95 342.13. Households well-endowed with assets are likely to use their assets to adapt to the adverse effects of climate change, thereby improving their livelihood outcomes.

Extreme weather events like floods can significantly affect physical assets such as roads, leading to disruptions in farmers' ability to access markets. For example, in the focus group discussions, farmers explained that they experienced extreme flooding in the year 2000, and damaged roads, houses and crops. As a result, their livelihoods were negatively affected. In early 2021, tropical storm Eloise left a trail of destruction in the uMkhanyakude district. Homes were flooded, and household items were destroyed.

Farmers who owned boreholes were also struggling to get water. Farmers explained that floods were not a problem in the uMkhanyakude district. The main challenge was drought. The drought in the area forced households to buy tanks to harvest water when there is rainfall, thus putting an extra financial burden on a population with high unemployment levels. The lack of water threatened production, household food security, health, social well-being, and livelihoods. Women bore the burden when it comes to water shortage for domestic use since they had to travel long distances to obtain water and wait in queues for lengthy periods.

Livestock is another important asset that supports rural livelihoods and household well-being. It serves various functions for rural communities and is integral to their livelihoods, serving commercial and non-commercial purposes (Ndoro, Mudhara & Chimonyo, 2014). Livestock rearing, including cattle, provides a source of income and serves as a measure and store of wealth for households. Extreme weather events (such as drought) negatively impact livestock productivity and limit farmers' ability to make a living. For example, the 2015/16 drought in uMkhanyakude resulted in livestock mortalities, and farmers had yet to recover from the devastation during the study period. Figure 6.2 shows the pattern of observed local households' perception of the productivity of livestock-based livelihoods.

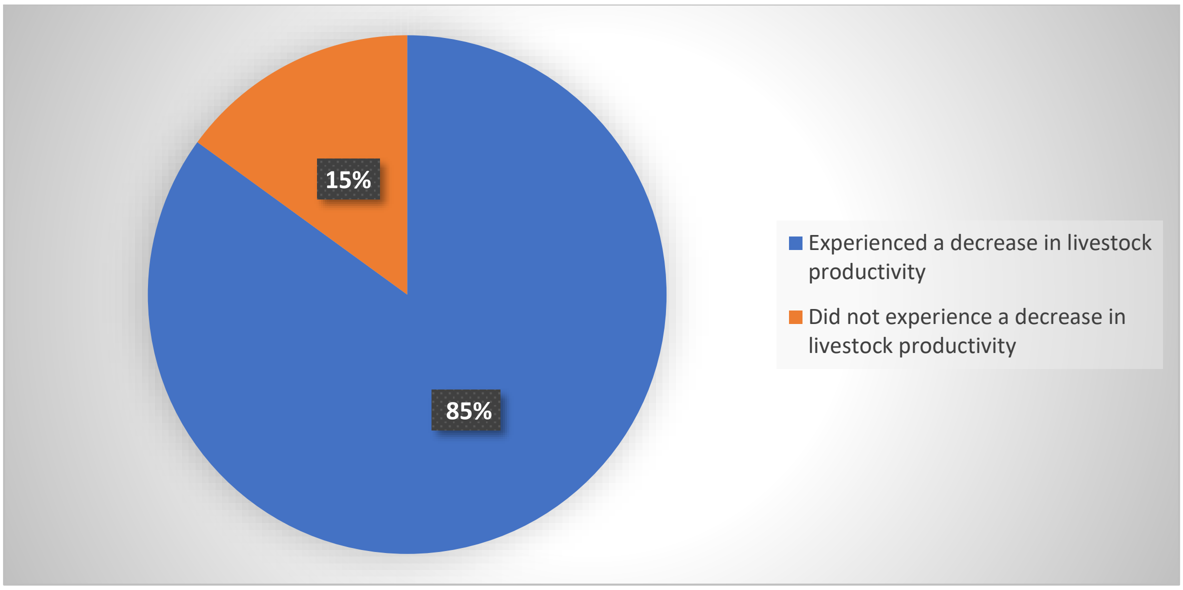

Figure 6.2: Farmers' Perceived Effect of Climate Change on Livestock Productivity

About 85% of the sampled households indicated that livestock productivity declined during the reference period (1999-2019) due to climatic changes. Farmers acknowledged that the health and quality of their remaining livestock had deteriorated dramatically, negatively impacting their trading prospects and the productivity of draught power. Increased water scarcity, forest depletion, and declining pasture availability and quality affected livestock production. Fodder shortages, due to drought, compelled farmers to sell their livestock at uneconomically low prices. A respondent in the focus group said:

The rains do not pour the way they used to 20 years ago and our animals are suffering. In the yesteryear's rains will fill dams and our animals will drink water from nearby dams and rivers. Yooh! Now animals have to travel a long distance to get drinking water because dams and rivers have dried up. (FGD 1)

Table 6.2: Human and Physical Assets of Smallholder Farmers

Variable code	Variable description and measurement	Mean	Standard deviation	Proportion
Human				
GENDER	Gender of household head (Male=1)	-	-	0.28
AGE	Age of household head (years)	55.77	12.36	-
EDUCAT	Years of schooling	7.14	4.74	-
TRAINING	Access to training (Yes=1)	-	-	0.55
FARMING_EXPERIENCE	Number of years in farming	17.02	13.81	-
H_ADULTS	Number of adult equivalent members residing in the household (continuous)	4.25	3.76	-
Physical				
TARRED_ROAD	Distance to tarmac road (km)	3.01	0.13	-
TLU	Tropical Livestock Units	8.13	12.23	-
TOT_ASSETV	Value of household assets (Rands)	95342.13	135639.7	-

6.3.2.3. Natural Assets

Smallholder farmers in the study area rely heavily on natural assets, such as land and water, for their livelihoods. These resources are vital for agricultural activities and key to the farmers' overall well-being. Rivers, boreholes, and dams are the most common water sources in the uMkhanyakude district. Table 6.3 shows that most land (50%) is allocated to households by the local authority. On average, smallholder farmers in the study area can access 1.31 hectares of land. The majority (74%) of the farmers indicated that they were satisfied with the size of their land holdings.

Like other rural communities in sub-Saharan Africa, the livelihoods of smallholder farmers in the uMkhanyakude district rely heavily on rainfall for agricultural activities. Below-average rain in the area has resulted in decreased soil moisture and a subsequent decrease in crop yields, necessitating farming households to depend on food purchases. Farmers perceived that rainfall patterns had changed and became unpredictable, negatively affecting their farming operations. This observation aligns with the explanation provided by Ncha (2014) that smallholder farmers experience notable reductions in crop yields due to shorter planting seasons and unpredictable rainfall patterns. High temperatures were also a cause for concern as they increased evapotranspiration and exacerbated soil moisture loss.

Farmers perceived that the condition of arable land in the study area had deteriorated over the years. Continuous seasons of drought resulted in limited soil cover as the topsoil is easily washed away with heavy rainfall. This has resulted in soil erosion, making it difficult to plant in some fields. Focus group participants also pointed out that they had to shift to drought-resistant crops such as cassava due to the prevailing dry conditions. However, some discussants argued that although they had to change to new crops, such crops did not replace maize, the staple crop. They still had to buy maize meal and samp from the shops. A focus group participant said:

My household has two fields and we are no longer using them because we do not receive enough rains in this area. We are now using a backyard garden because it is easy to irrigate. In the previous years we used to grow maize in summer but all that has changed because we do not receive enough rains. Most households in this area have resorted to planting cassava because it grows even if we do not get the rains that we expect. (FGD 2)

Forest resources are a critical natural asset that households depend upon for a living. Most (78%) households reported that forest resources have decreased over the past 20 years due to the changing climate. Dwindling forest resources reduced households' chances of obtaining raw materials for constructing houses, agricultural working equipment and wooden cutlery, among other products derived from the forest. A focus group member elaborated:

I grew up in this community and got married here, our fathers used to hunt wild animals and we never struggled to get meat. However, things have changed, my grandkids hardly get rabbits in the bush, there is not enough food to reproduce. On the issue of wild fruits, this area is known for producing marula beer in this district. Previously, we used to harvest enough to make beer and people will come from other areas to buy marula beer from us. However, that *is no longer the case, it is dry here, and we no longer get a satisfactory harvest, which has affected our income. During January and February, we used to harvest mopani worms from marula trees and the worms have decreased, this has affected us since we used to get money from selling the worms. (FGD 2)*

Figure 6.3 shows the pattern of observed local households' perception of climate change on the availability of natural resources. Forest resources such as wild plants and animals have provided food and nutrition security to African communities for centuries.

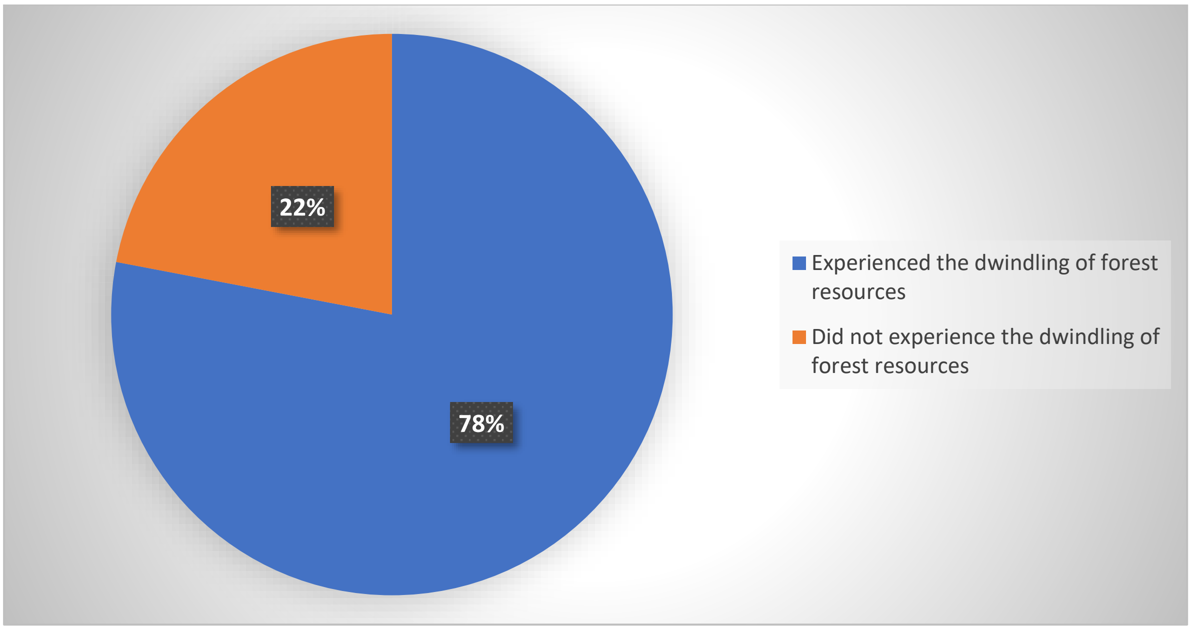

Figure 6.3: Farmers' Perceptions of the Impact of Climate Change on Forest Resources

Rural households depended on streams and rivers for water for various livelihoods, such as the irrigation of crops and fishing. Figure 6.4 shows that 83% of the sampled farmers experienced the drying of rivers and streams due to climate change.

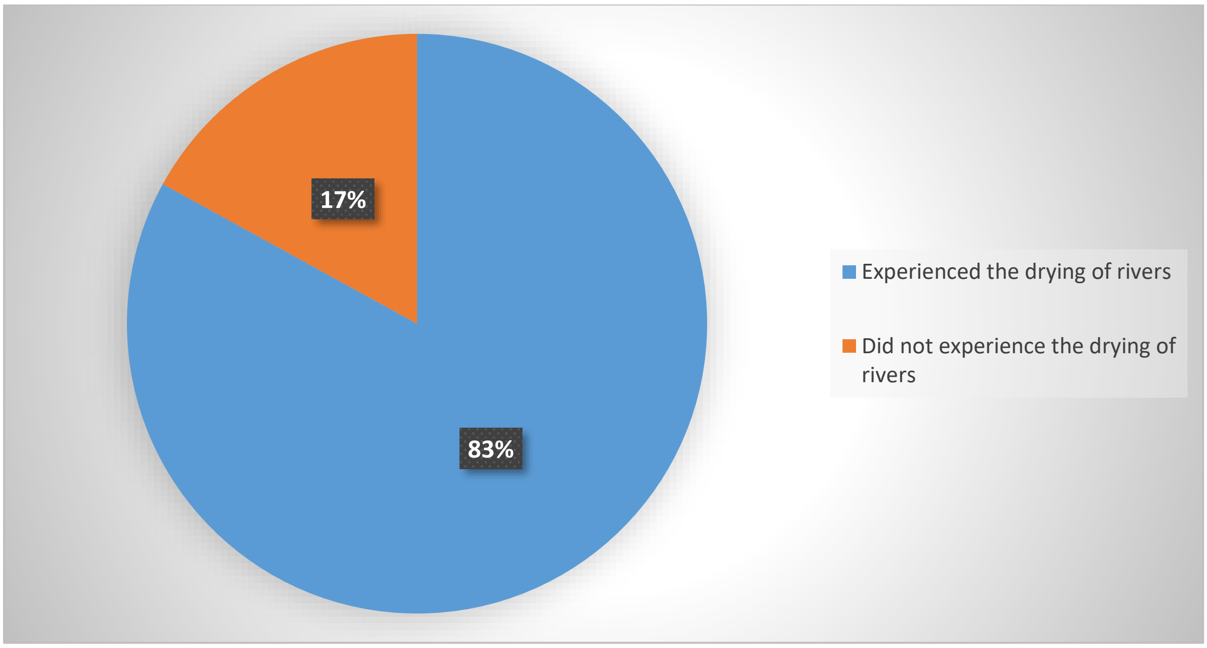

Figure 6.4: Farmers' Perceived Effect of Climate Change on Water Availability

Changing rainfall and temperature regimes have impacted the availability of various forest resources in the area, including wild fruits, timber, and wild animals. Wild fruits and animals, in particular, act as coping mechanisms when food is scarce and a supplement when there is a food surplus. The study area's forest resources are also under climate-induced pressures such as wildfires.

6.3.2.4. Financial Assets

Climate change negatively impact on financial assets. Financial capital assets, which encompass cash, savings, wages from employment, access to credit sources, remittances, and government social grants, play a crucial role in helping households achieve their livelihood outcomes. These assets serve as a buffer for rural households against the various stressors associated with climate change.

Table 6.3 shows that 87% of the households were social grant beneficiaries. The South African government provides social grants to qualifying poor households to cushion them against poverty and food insecurity. During the focus group discussions, farmers expressed that during favourable seasons, they utilised the funds obtained from social grants to purchase essential household items like cooking oil and soap, which were beyond their production capabilities. As a result of the prevailing drought conditions, farmers revealed that they had to rely on social grants for food purchases to sustain their livelihoods.

About 53% of households indicated that they obtained credit between August 2019 and August 2020, mainly from stokvels[1] or savings groups. Such credit is usually used to buy farm inputs during crop growing. Harsh climatic conditions in the previous years resulted in poor yields, and farmers could not sell surplus produce to pay back the loans. Table 6.2 indicates that 64% of smallholder farmers were in savings groups. Farmers mentioned that during the 2015/16 drought, they used a considerable proportion of their savings to purchase fodder for livestock. They argued that the savings were diverted from household responsibilities such as buying school uniforms for school children and renovating houses, thus depriving households of necessities. The average monthly income of households is about R4639.50. On average, a household in the sample has four adult equivalent members whose income levels are low to support their food requirements. According to the Bureau for Food and Agricultural Policy annual baseline report (BFAP, 2021), a food basket for a family of three people in South Africa costs R2 932. These estimates imply that low-income households with larger family sizes will struggle to procure a food basket that will allow them to eat an adequately diversified diet.

Moreover, the adverse employment and income effects because of COVID-19 will negatively impact on household income. This, in turn, will likely impede the progress made in achieving food security over the past decade. Excessive rains from tropical cyclones and drought will compound the plight of smallholder farmers and further erode their livelihoods.

[1] A stokvel is made up of a collective of individuals who pool their resources together and contribute a predetermined amount of money each month with the goal of achieving a specific target. At the end of the financial year, members receive dividends based on their contributions.

Table 6.3: Natural, Financial and Social Assets of Smallholder Farmers

Variable code	Variable description and measurement	Mean	Standard deviation	Proportion
Natural				
LAND_SIZE	Land size in hectares (ha)	1.31	1.20	-
LANDALLOC	Land allocated by traditional authority (Yes=1)	-	-	0.50
LANDTENURE_SATISFA	Land tenure satisfaction (Yes=1)	-	-	0.74
LAND_INHERIT	Land inherited from family members (Yes=1)	-	-	0.33
Financial				
TOTAL_INCOME	Total annual income (Rands)	55674.49	32568.76	-
CREDIT	Access to credit (Yes=1)	-	-	0.53
SAVINGS_GROUP	Membership in savings group (Yes=1)	-	-	0.64
GOV_GRANT	Access to government grant (Yes=1)	-	-	0.87
Social				
FARM_ASSOC	Membership in farmers' association (Yes=1)	-	-	0.35
TRUST	Number of people household head can revert to in times of need	4.7	5.3	-

6.3.2.5. Social Assets

Social assets entail social resources that households rely upon to meet their livelihood outcomes. Social assets play an important role in unlocking the potential benefits of other capital assets, particularly in facilitating collective action activities where a group of individuals collaboratively work towards achieving a shared objective (Muchara *et al*., 2014). These networks are among households and are based on trust and social ties. Farmer engagement in associations, interpersonal connections, networks, and linkages are among the social resources that households utilise to support their livelihoods. Social assets can be formal and informal (Aniah *et al*., 2016). Table 6.3 shows that about 35% of the sampled farmers were members of a farmers' association. Farmers involved in associations indicated that they attended training in their farmer groups, and livestock farmers, in particular, used associations to share information about livestock diseases and treatment methods. Farmer groups were also used for bulk buying farm seeds, fertilisers, and chemicals. On average, households had five community members they can revert to in times of need. These findings indicate points to weak social networks in uMkhanyakude. This also suggests that farmers may not receive assistance during times of crisis. The low participation of farmers in associations reveals a fragmented social network in the district, which could hinder farmer development and adaptation to climate change. Cishahayo, Zhu, Zhang & Wang (2023) demonstrated that farmers who enhance their social capital improve access to information and knowledge of new strategies to improve productivity under climate change, thereby improving their livelihoods.

The findings from the focus groups revealed that in the immediate aftermath of a climatic disaster, farmers survive by drawing support from social networks. However, with the intensity and regular occurrence of natural disasters like drought, social cohesion alone is not enough. Relief programmes during or after the drought also creates disputes between beneficiaries and non-beneficiaries. Consequently, the tensions between farmers loosens social bonding. A focus group member elaborated:

After the drought we were told to register our names and we did as recommended by the extension officers. However, it is not everyone who registered that received the inputs and the criteria the criteria used was not clear to everyone. Moreover, this has created conflicts among farmers. (FDG1)

6.3.3. Livelihood Outcomes of Smallholder Farmers

Khatiwada, Deng and Paudel (2017) define livelihood outcomes as the benefits of engaging in livelihood strategies. These outcomes encompass various aspects, such as income generated from selling agricultural goods and achieving food and nutrition security. About 35% of the sampled farmers reported having experienced regular food shortages between August 2019 and August 2020, while 54% reported having experienced occasional food shortages in the same period. Farmers argued that they couldn't plant their fields due to dry conditions. In the same vein, those who planted summer crops did not get enough harvest because of dry conditions and this has forced farmers to rely heavily on cash purchases. Most farmers in the study area depend on social grants and these government transfers are not enough for their monthly household food basket. Declining household incomes in the study area were attributable to climatic change. Focus group discussions revealed that yields from crop farming had significantly been reduced in the previous years and this had negatively affected income derived by smallholder farmers from the sale of their agricultural products. The persistent drought in the area also decreased yields from Mopani worms which are usually used in summer as a source of protein and a substitute for meat. Some farmers in the area also practised gardening to supplement household dietary requirements. Persistent drought and poor municipal water supply forced households to abandon household gardens.

6.4. SUMMARY

This chapter has used the Sustainable Livelihood Framework to examine climate change's perceived impact on farmers' livelihoods in the uMkhanyakude district. The results revealed that smallholder farmers relied on various capital assets to sustain their livelihoods. The results suggest that climate change has eroded the capital assets that smallholder farmers depend upon to create a livelihood. Women constitute most smallholder farmers and, by implication, are more vulnerable to the adverse effects of climate change. Farmers in the uMkhanyakude district are mainly involved in crop and livestock production.

Drought has been a prominent feature in the uMkhanyakude district. Persistent drought has resulted in decreasing yields, thus forcing households to rely heavily on food purchases rather than their own production. Climate change has also resulted in the dwindling of forest resources, which negatively impacted the income of local households. Forest depletion and deteriorating pasture quality have negatively affected livestock production. Ultimately, climate change decreased household incomes and increased food insecurity in communities dependent on rainfed agriculture. These findings indicate that the livelihoods of smallholder farmers are at risk due to climate change.

CHAPTER 7: SMALLHOLDER FARMERS' CHOICE OF CLIMATE CHANGE ADAPTATION STRATEGIES IN THE UMKHANYAKUDE DISTRICT

7.1. INTRODUCTION

Climate change adaptation strategies are measures individuals take to mitigate the adverse impacts of climate change (Mugambiwa, 2018). These strategies can be reactive, addressing current climate events, or proactive, preparing for future climatic changes. Adaptation to climate change involves two steps: recognising the presence of climate change and acting by implementing strategies to mitigate its negative effects, thereby reducing human and economic losses. Successful adaptation depends on the ability and willingness of smallholder farmers to adapt (Mugambiwa, 2018). In the absence of adaptation, the detrimental effects of climate change tend to be severe.

There is a plethora of studies that have documented adaptation to climate change in Africa (Komba & Muchapondwa, 2018; Asfaw *et al*., 2019; Marie *et al*., 2020) and area-specific studies that have focused on South Africa (Lottering, Mafongoya & Lottering, 2021; Shisanya & Mafongoya, 2016; Kom *et al*., 2022). The continental and local-level studies generally agree that local-level climate change adaptation is critical to improving smallholder farmers' resilience (Abegunde, Sibanda & Obi, 2019; Awazi *et al*., 2019). Studies have shown that climate change adaptation can enhance crop productivity, particularly in regions prone to drought (Abate *et al*., 2015; Fisher *et al*., 2015; Lunduka *et al*., 2017). Common adaptation strategies in agriculture include planting drought-resistant crops, introducing livestock breeds that can withstand harsh climatic conditions, adjusting planting dates, implementing mixed farming practices, and irrigation and adopting mixed cropping systems (Wale, Nkoana & Mkuna, 2022; Asfaw *et al*., 2019; Marie *et al*., 2020; Lottering *et al*., 2021).

This chapter aimed to examine the factors influencing smallholder farmers' choice of adaptation strategies. Limited knowledge exists regarding farmers' adaptation strategies and their determining factors in the uMkhanyakude district. Gaining insights into farmers' decision-making process for climate change adaptation and its determinants enhances comprehension of how smallholder farmers cope with climate change. The findings on local adaptation strategies hold the potential to guide the formulation of appropriate adaptation policies that cater to the requirements of local farmers.

7.2. CONCEPTUAL FRAMEWORK

Willock *et al*. (1999) argue that development economists are concerned about understanding the processes and consequences of the decisions undertaken by smallholder farmers. The literature on farmers' technology adoption is premised on normative theory and the assumption that the farmer is always looking to maximise profit. However, this is not always the case; hence such approaches fail to capture the complexities driving farmers' decisions (Austin *et al*., 1998). These theories fail to acknowledge that farmers' decisions are not solely motivated profit maximisation (Willock *et al*., 1999).

The decision taken by farmers in the implementation of climate change adaptation strategies is generally considered under the theoretical framework of utility. The smallholder farmer is concerned about keeping the same level of agricultural productivity despite the challenges posed by climate change (i.e., prolonged drought periods). It follows that a smallholder farmer would choose a climate change adaptation strategy if the productivity derived from that strategy exceeds the productivity derived from selecting an alternative adaptation method. The utility of implementing a climate change adaptation strategy is not observable. Instead, what can be observed are the adaptation choices made by smallholder farmers. Let M_b represent the utility of a smallholder farmer for choice P_b and M_c denote the utility of a farmer for choice P_c. The utility model can be expressed as follows:

$$P_b = \beta_b \mathrm{X}_i + \varepsilon_b \text{ and } P_c = \beta_c \mathrm{X}_i + \varepsilon_c$$

Where P_b and P_c are the perceived utilities of climate change adaptation methods b and c, respectively, X_i is the vector of explanatory variables that influence the perceived desirability of the method, β_b and β_c are parameters to be estimated and ε_b and ε_c are error terms assumed to be independent and identical (Deressa *et al*., 2008).

If a smallholder farmer chooses option b, it follows that the utility derived from choosing option b is greater than the perceived utility of choosing other adaptation methods, and this can be presented as:

$$P_{bi}(\beta_b \mathrm{X}_i + \varepsilon_b) > (P_{ci}(\beta_c \mathrm{X}_i + \varepsilon_c),\ b \neq c$$

7.3. DATA ANALYTICAL METHODS

7.3.1. Empirical Model: Dependent Variable and Model Specification

The Multinomial Logit Regression (MNL) model was employed to analyse the determinants of farmers' choice of adaptation strategies. The MNL model offers several advantages, such as analysing decisions involving multiple categories and estimating choice probabilities for each category (Madalla, 1983). It has been widely used in studying crop and livestock choices for climate change adaptation (Ubisi *et al*., 2017).

Using an MNL model has the benefit of being computationally simple for determining analytically expressible decision probabilities (Tse, 1987). It provides a straightforward closed form for calculating choice probabilities without requiring multivariate integration, facilitating the assessment of choice scenarios with multiple alternatives (Tse, 1987). In addition, the likelihood function of the MNL model specification is globally concave, which reduces computational complexity (Hausman & McFadden, 1984). However, the MNL model has a weakness known as the Independence of Irrelevant Alternatives (IIA) property. This property assumes that the ratio of the probability of selecting any two choices is independent of any other attribute in the decision set (Hausman & McFadden, 1984).

During preliminary site visits, it was established that smallholder farmers were using four main distinct adaptation strategies. They included planting drought-resistant crops, shifting planting dates, practising mixed farming, and using irrigation. It was also established that some farmers did not adopt any climate change adaptation strategy. Consistent with previous climate change adaptation studies (Saguye, 2016; Debela, 2017), the dependent variables in this study are binary and were assigned a value of 1 if the farmer implemented the specific adaptation strategies and 0 if the farmer did not employ them. This approach was adopted to distinguish between farmers who successfully adapted to climate change and those who did not. For this study, a farmer is considered to have adapted to climate change if they implemented at least one of the following adaptation strategies: planting drought-resistant crops, adjusting planting dates, practising mixed farming methods or utilising irrigation. The MNL logit model is expressed as follows:

The dependent variable is the adaptation strategy adopted by the farmer (1= Drought-resistant crops; 2= Shifting planting dates; 3= Mixed farming; 4= Irrigation; 5= No adaptation). Let A_j= (j= 1, 2, 3, 4) be the probability of each smallholder farmer being in each adaptation strategy and j=5 being the base category (no adaptation). According to Greene (2003), the MNL model for the choice of adaptation strategies expresses the relationship between the probability of a farmer being in a particular adaptation option and a set of explanatory variables. The model is expressed as follows:

$$A_j = \mathrm{I_n}\ (A_j / A_5) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + ei$$

where:

A_j = adaptation strategy (1= Drought-resistant crops; 2= Shifting planting dates; 3= Mixed farming; 4= Irrigation)

In= the natural logarithm

A_5= base category (no adaptation)

β_0 = constant term.

$\beta_1, \beta_2 \ldots \beta_{12}$ = regression coefficients of the explanatory variables.

$X_1, X_2 \ldots\ldots X_{12}$ = explanatory variables.

$e_{i=}$ error term.

According to Deressa *et al.* (2009), the parameter estimates derived from the MNL model indicate only the direction of the influence of independent variables on the dependent variable. These estimates do not quantify the actual magnitude of change or probabilities. Marginal effects are used to interpret the impact of the explanatory variables on probabilities. The marginal effects are calculated as follows:

$$\partial_j = \frac{\partial A_j}{\partial X_i} = A_j\left[\beta_j - \sum_{k=0}^{j} A_j\, \beta_k\right] = A_j\left(\beta_j - \beta^{-}\right)$$

According to Greene (2000), marginal effects measure the anticipated change in the probability of a specific adaptation strategy being chosen in response to a unit change in an explanatory variable. Some statistical concerns, such as multi-collinearity, were assessed for the hypothesised independent variables. The Variance Inflation Factor (VIF) was employed to detect multi-collinearity among continuous explanatory variables. The correlation matrix approach was used to determine the degree of relationship between dummy explanatory variables. Variables are considered collinear if the coefficient correlation matrix exceeds 0.4. Multicollinearity is also present when the correlation coefficient value exceeds 0.4 (Long & Freese, 2006).

The data used in the study was checked so that it complies with the six assumptions of the MNL model. The outcome variable has more than two categories and there is no given order. The outcome variable (climate change adaptation methods), was mutually exclusive and exhaustive. This assumption is a limitation of the MNL is that it assumes that the farmer implemented one adaptation strategy. In practice, farmers implement a variety of climate change adaptation strategies. Farmers were allowed to pick one adaptation strategy. Observations were also independent of each other. The independent variables were checked for multiclonality and it was not a problem within the variables. Moreover, there were no outliers or highly influential points in the model. The relationship between the continuous variables and logit transformation was linear.

7.3.2. Independent Variables and Working Hypothesis

The model incorporates a range of explanatory variables hypothesised to influence farmers' choice of adaptation strategies. These variables include various factors, such as demographic, socioeconomic, and institutional characteristics that shape the farming landscape. A review of previous studies on climate change adaptation and data availability guided the inclusion of specific explanatory variables in the model. Table 7.1 provides details of the variable names, descriptions, and anticipated signs within the model.

Table 7.1: Variables Used in the Multinomial Logit Regression Model

Variable code	Variable name	Variable description and measurement	Expected sign
AGE	Age	Age of household head in years (continuous)	+
GENDER	Gender	1= male and 0 otherwise (dummy)	-
EDUCAT	Education	Years of schooling (continuous)	+
LAND_SIZE	Land size	Land size in hectares (continuous)	+
TOTAL_INCOME	Farm and off-farm income	Total amount of money received by the household in the previous year (continuous)	+
H_ADULTS	Number of adult equivalents	Number of adult equivalent members residing in the household (continuous)	+
EXTENSION	Access to extension	1 if the farmer has access to extension services and otherwise	+
TLU	Tropical Livestock Units	Livestock size per household (TLUs)	+
MARKET_ACCESS		1 if respondent has access to markets and 0 otherwise (dummy)	+
CREDIT	Access to credit	1 if respondent received credit in the previous year and 0 otherwise (dummy)	+

The age (AGE) of the household head is a continuous variable and has been used as a proxy for farming experience. The literature presents conflicting findings regarding the influence of age on households' decisions to adapt to climate change. Kom *et al*. (2022) and Amare and Simare (2017) indicated that age did not significantly impact farmers' choices of climate change adaptation strategies. However, other studies (Adimassu & Kessler, 2016; Opiyo *et al*., 2016; Alemayehu & & Bewket, 2017) found that age played an important role in adopting climate change adaptation strategies. In the present study, it is hypothesised that age will positively affect adopting climate change adaptation strategies.

The gender (GENDER) of the household head is a binary variable, with a value of 1 indicating a male farmer and 0 showing a female farmer. The influence of gender on the decision to adapt to climate change is mixed. Some studies (Hitayezu, 2015; Amare & Simane, 2017) have found that women play an active role in adopting natural resource management practices. However, Belay *et al*. (2017) showed that males have a better chance of adopting adaptation measures than females. It is hypothesised that the gender of the household head will exert either a negative influence on climate change adaptation.

Education (EDUCAT) is a continuous variable that represents the household head's educational attainment, measured in years of schooling. Amare and Simane (2017) found that education plays a vital role in influencing adaptation decisions. Farmers with a higher level of education are presumed to possess greater knowledge and understanding of climate change and agricultural techniques, enabling them to respond to the evolving climate conditions effectively. Thus, education is hypothesised to positively influence climate change adaptation.

Access to extension services (EXTENSION) is a dummy variable, taking 1 if the farmer had access to extension services and 0 otherwise. Extension services play a crucial role in disseminating agricultural and climate-related information, enabling farmers to gain a deeper understanding of adaptation practices (Amare & Simane, 2017). Hence, access to extension services facilitates the adoption of climate change adaptation strategies. The variable is expected to have a positive effect on climate change adaptation.

Access to credit (CREDIT) is a dummy variable that takes 1 if the farmer had access to credit and 0 otherwise. Several studies (Okonya & Kroschel, 2014; Atube *et al*., 2021; Belay *et al*., 2017) have demonstrated the significant impact of credit accessibility on adopting innovative technologies that facilitate climate change adaptation. By resolving cash flow limitations, access to credit enables farmers to support their farming operations financially. Therefore, access to credit is anticipated to positively affect climate change adaptation.

Total income (TOTAL_INCOME) is a continuous variable representing both farm and off-farm income reflecting the household’s wealth. Knowler and Bradshaw (2017) found that adopting agricultural technologies necessitates a certain level of financial capital. Thus, it is hypothesised that higher farm and non-farm income levels will positively influence adopting climate change adaptation strategies.

Access to markets (MARKET_ACCESS) is a dummy variable, assuming 1 if the household had access to markets and 0 otherwise. Access to markets plays a crucial role in climate change adaptation because it facilitates the movement of inputs and outputs and information on adaptation options (Alemayehu & Bewket, 2017). Therefore, access to markets is anticipated to have a positive effect on climate change adaptation.

Land size (LAND_SIZE) is a continuous variable indicating the number of hectares owned by the household. Existing literature on adaptation suggests that the adoption of innovations tends to occur earlier on larger farms than smaller ones. Daberkow and McBride (2003) demonstrated that there might be a critical lower limit on farm size that hinders smaller farms from adapting, primarily due to the uncertainty and fixed costs associated with innovation-related transactions and information. As these costs increase, the critical size threshold also rises. Consequently, smaller farms are less likely to adopt innovations with a substantial fixed transaction or information costs. This notion is supported by a study conducted in the Limpopo province of South Africa, which found a positive correlation between farm size and the likelihood of choosing irrigation, drought-resistant crops, improved cultivars, and mixed cropping as climate change adaptation methods (Kom *et al*., 2022). Therefore, farm size is expected to positively influence climate change adaptation.

Adult equivalent (H_ADULTS) is a continuous variable that represents the availability of labour in the household. The variable adjusts for age differences in the home. The impact of adult equivalent on adapting to climate change is mixed. Adopting new innovations may be positively influenced by household size, which is a proxy for labour availability (Gbetibouo *et al*., 2010). Larger family sizes can reduce labour constraints, making households with more members more inclined to adopt innovations. However, households with larger family sizes may also face pressures to allocate a portion of their labour force to non-farm activities to address consumption needs arising from the larger family size (Amane & Simare, 2017). Therefore, family size can positively and negatively affect climate change adaptation.

Livestock is a basic and essential livelihood asset for rural communities. In quantifying livestock resources, all animals owned by the household were aggregated using TLUs.

7.4. RESULTS AND DISCUSSION

7.4.1. Socioeconomic Characteristics of the Sampled Farmers

Data were analysed using STATA version 15. Descriptive statistics were employed to analyse the variables used in the model and the barriers to adaptation. Descriptive statistics were summarised and presented as means, proportions and in bar charts.

Table 7.2 presents the variables included in the MNL model and their respective means and proportions. The findings indicate that 28% of the sampled farmers were males, whereas 72%

were females. These results align with previous studies conducted in the KwaZulu-Natal province (Lottering *et al*., 2021) and Limpopo province (Kom *et al*., 2022) of South Africa. These findings imply that women constitute most smallholder farmers in South Africa, suggesting that they are particularly susceptible to the adverse impacts of climate change since they are involved in dryland cropping. The average age of smallholder farmers is 55.77 years, indicating that the study area predominantly consists of older individuals engaged in smallholder farming. This demographic composition raises concerns about the sustainability of smallholder farming in the uMkhanyakude district. Nevertheless, the reliability of the results is bolstered by the fact that the average age of smallholder farmers is 55.77, as this study focused on a 20-year reference period. Moreover, in Nigeria, Obayelu, Adepoju and Idowu (2014) found that older people were more active in farming compared to younger people. On average, households in the uMkhanyakude district had approximately five adults during the study. These results conform to earlier findings about the composition of agricultural households in KwaZulu-Natal (Hitayezu *et al*., 2017).

On average, smallholder farmers had attained 7.14 years of schooling, implying that most farmers in the local area did not go beyond primary education. The low levels of education (EDUCAT) in the study area may potentially hinder the adoption of agricultural innovations. Studies (Muzangwa, Mnkeni & Chiduza, 2017; Marenya et *al*., 2017) have shown that education is critical in enhancing understanding and facilitating the uptake of adaptation strategies.

The findings indicate inadequate levels of institutional support provided by the government. Approximately 19% of smallholder farmers received extension services between August 2019 and August 2020, implying that very few farmers were visited by extension officers during the reference period. The limited access to extension services (EXTENSION) has broader implications on their ability to adopt innovative climate change adaptation strategies that could mitigate the adverse effects of climate change. These results align with previous studies that reported only 13.6% of agriculturally active black households in the KZN province received agricultural support in 2017 (Stats SA, 2018).

More than half (53%) of the sampled smallholder farmers reported having access to some form of credit (CREDIT). However, previous studies conducted in South Africa (Myeni *et al*., 2019; Khapayi & Celliers, 2016) have highlighted the limited access to credit among households due to low income, advanced age, and low levels of education. Focus group discussions revealed that most farmers in the uMkhanyakude district had access to informal credit sources such as stokvels, friends and family members. These findings emphasise the significant role of social networks as essential sources of credit, providing much-needed funding for smallholder farmers.

The average land size (LAND_SIZE) controlled by farmers was 1.31 hectares. This result aligns with previous studies that reported that most smallholder farmers in South Africa own less than 2 hectares of land (Mpandeli & Maponya, 2014; Von Loeper *et al*., 2016). The study results indicate that market access (MARKET_ACCESS) was not a problem in the uMkhanyakude district. Those involved in the two irrigation schemes in the Jozini local municipality sold their produce to bakkie traders who were mainly from Richards Bay and the port city of Durban. However, farmers lamented in the focus groups that they mostly get orders in winter since they can plant summer crops in winter because of the warm temperatures.

Table 7.2: Summary Statistics of the Sampled Smallholder Farmers

Variable code	Variable description	Mean	SD
AGE	Age of household head in years	55.77	12.36
GENDER	Gender of the household head (Male=1)	0.28	-
EDUCAT	Years of schooling	7.14	4.74
LAND_SIZE	Land size in hectares (ha)	1.31	1.20
MARKET_ACCESS	Access to output markets (Yes=1)	0.62	-
H_ADULTS	Number of adult equivalents	4.25	3.76
TLU	Tropical Livestock Units	8.13	12.23
CREDIT	Access to credit (Yes=1)	0.53	-
TOTAL_INCOME	Total annual income (Rands)	55674.49	32568.76
EXTENSION	Access to extension services (Yes=1)	0.19	-

To mitigate climate risk, smallholder farmers in the uMkhanyakude district implemented various climate change adaptation strategies. Figure 7.1 depicts the overall adaptation strategies employed in the region, and mixed farming is the most widely used adaptation strategy. About 37.25% of the sampled farmers practised mixed farming. One major observation from the field was that goats were the most common livestock in the uMkhanyakude district, while maize was the most widely grown crop. Key informants confirmed that goats were most common because they do well in harsh climatic conditions similar to the conditions experienced in uMkhanyakude.

Figure 7.1 shows that 16.5% of the surveyed farmers were adjusting planting dates as an adaptation strategy against the adverse impacts of climate change. Similar findings have been reported in South Africa (Taruvinga, Visser & Zhou, 2016; Ubisi *et al.*, 2017) and Togo (Gadédjisso-Tossou, 2015). Approximately 17.25% of the smallholder farmers planted drought-resistant crops to adapt to climate change. Previous studies (Kom *et al.*, 2022; Vilakazi, Zengeni & Mafongoya, 2019) conducted in South Africa have shown that farmers living in harsh climatic conditions are shifting to drought-resistant crops. In the focus group discussions, farmers indicated they were also planting crops such as cassava and sweet potatoes since these crops have minimal water requirements. Irrigation is one way of enhancing crop production by reducing dependency on rainfed agriculture. A small proportion (4.5%) of the smallholder farmers used irrigation as a form of adaptation. Extension officers in the area echoed this result. They agreed that irrigation is not well developed and the support received by smallholder farmers regarding irrigation infrastructure was limited and insufficient to support irrigation as a widely used adaptation strategy adequately.

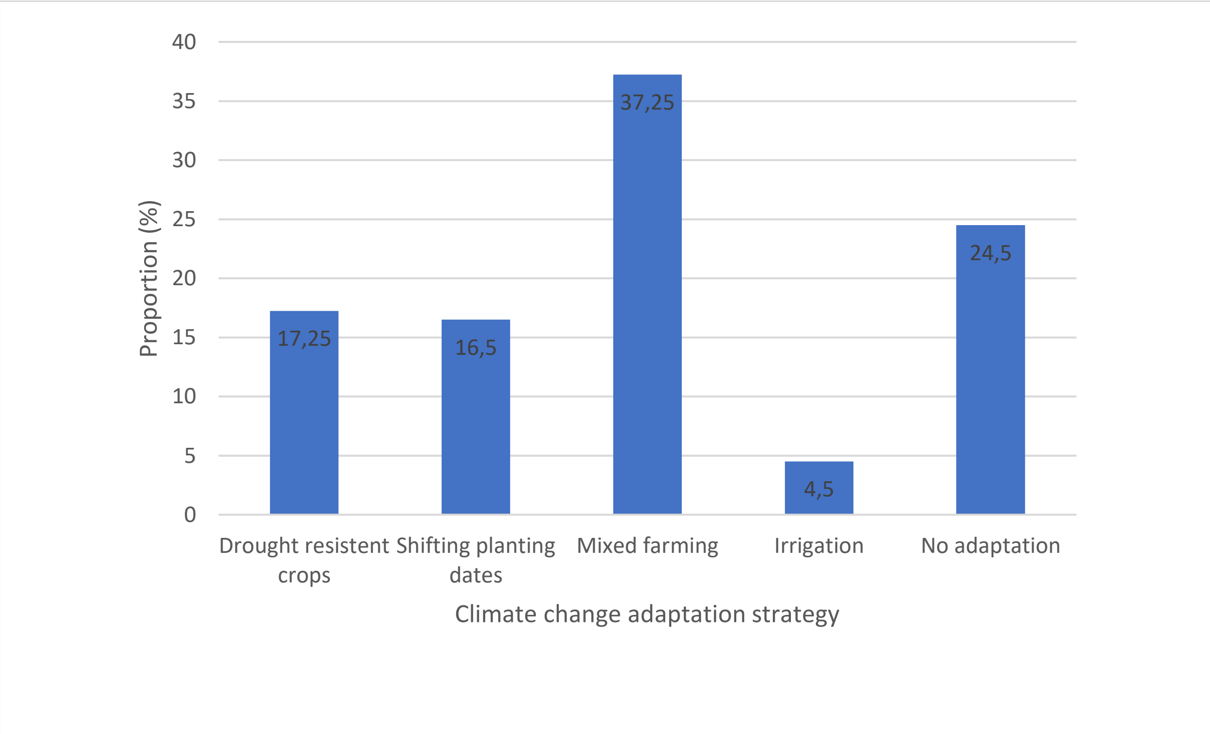

Figure 7.1: Climate Change Adaption Strategies

They further explored the barriers hindering climate change adaptation. Figure 7.2 shows that farmers identified lack of information, insufficient financial resources, scarcity of labour and limited availability of land as the barriers to climate change adaptation. Among the surveyed farmers, a significant proportion (70%) cited a lack of information as a significant barrier to climate change adaptation. Around 60% of the farmers identified a lack of financial resources as a constraint impacting their ability to adapt to climate change. In addition, 23% of the sampled farmers reported labour shortages, while 20% mentioned limited land as a limiting factor. These findings align with the results of Wale *et al*. (2022), which reported that a lack of information, financial constraints, and labour shortages were the main factors impeding climate change adaptation in the KwaZulu-Natal province of South Africa. In the focus groups, some farmers echoed the sentiment that they had not interacted with an extension agent between August 2019 and August 2020, and this explains the high proportion (70%) of farmers who indicated a lack of information as a barrier to climate change adaptation.

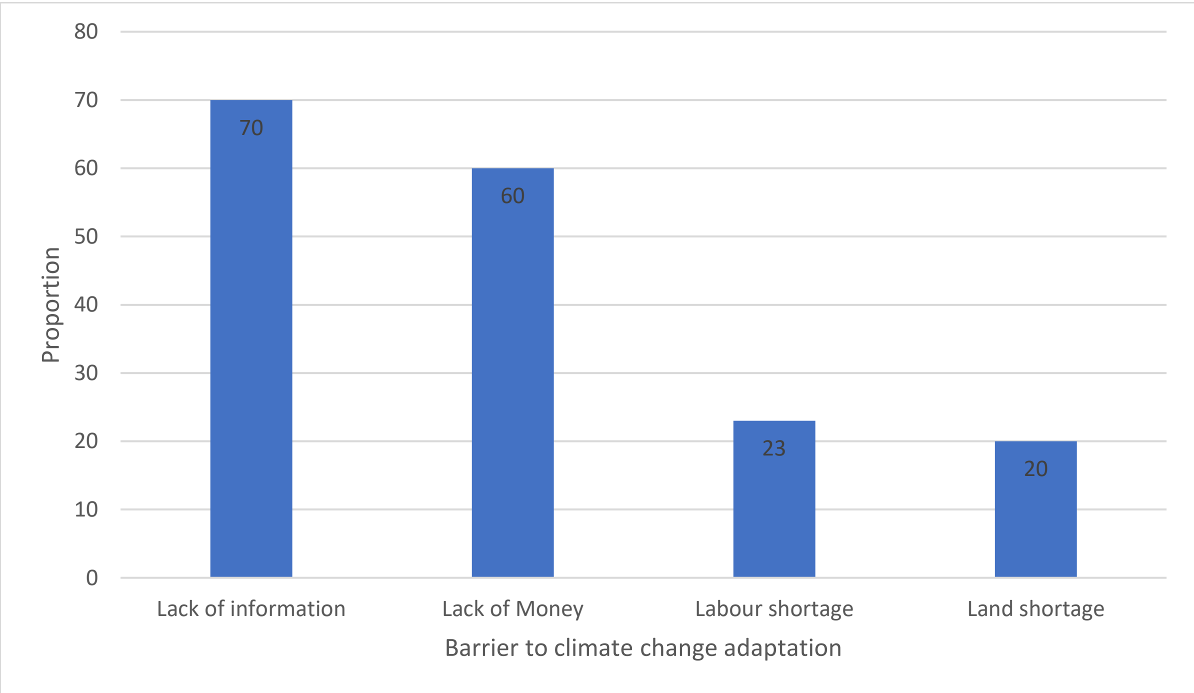

Figure 7.2: Barriers to Climate Change Adaptation

7.4.2. Determinants of Farmers' Choice of Adaptation Methods

The MNL model was used to analyse the factors influencing farmers' adaptation strategies. The MNL model in this study was employed by normalising one category, also called the base or the reference category. In addition, the Ordinary Least Squares (OLS) model was applied to assess multicollinearity using the Variance Inflation Factor (VIF) and highly correlated variables were removed from the regression model. Variables that were dropped included access to radio or TV (RADIO_TV), membership in social groups or farmer organisations and farming experience (FARM_EXPERIENCE). Table 7.3 presents the VIF values for the final ten variables that were included in the MNL model. With a mean VIF of 1.10, multicollinearity was not a problem, and the remaining variables were considered appropriate for the model. Correlations were also performed, and the remaining variables had coefficients less than 0.4, which is regarded as appropriate.

Table 7.3: Multicollinearity Test Between Independent Variables

Variable code	**Variance Inflation Factor (VIF)**	**Multicollinearity Tolerance**
AGE	1.03	0.967
GENDER	1.09	0.916
EDUCAT	1.03	0.973
LAND_SIZE	1.17	0.856
MARKET_ACCESS	1.11	0.900
H_ADULTS	1.15	0.870
TLU	1.23	0.811
CREDIT	1.09	0.915
TOTAL_INCOME	1.10	0.905
EXTENSION	1.01	0.990
MEAN VIF	1.10	

Table 7.4 displays the parameter estimates of the MNL climate change adaptation model, while Table 7.5 presents the corresponding marginal effects and their significance levels. The parameter estimates indicate the direction of the independent variables' impact on the dependent variable without providing the exact magnitudes of change. Instead, the marginal effects are reported, representing the expected change in the probability of selecting a specific adaptation strategy. The coefficients are compared to the base category of no adaptation.

To assess the assumption of independence of irrelevant alternatives (IIA) in the MNL model, a nested Logit model, an extension of the MNL, was employed (Hausman & McFadden, 1984).

A standard method involving a restricted choice set (shifting planting dates or irrigation alternatives) was used. The model exhibited no significant changes, and the results were further validated through the Hausman test (Long & Freese, 2006), which confirmed that the null hypothesis of IIA could not be rejected. Consequently, using the MNL model to estimate the determinants of climate change adaptation choice is deemed appropriate and justified.

7.4.2.1. Planting Drought-Resistant Crops

The results show a positive and statistically significant relationship ($p<0.1$) between access to extension services (EXTENSION) and the adoption of drought-resistant crops as a climate change adaptation strategy. This result is in line with the *a priori* expectation. The findings indicate that access to extension services increases the likelihood of farmers adopting drought-resistant crops by a factor of 0.046. This underscores the importance of extension officers as a valuable source of agricultural information for smallholder farmers. By accessing extension services, farmers can enhance their understanding of climate change and gain knowledge about suitable drought-resistant crop options specifically suited to their region. These results are consistent with previous studies that found a positive relationship between access to extension services and the adoption of drought-resistant crops as a climate change adaptation strategy (Carlisle, 2016; Myeni *et al*., 2019).

Consistent with the *a priori* expectation, the results revealed a positive and significant relationship ($p<0.01$) between access to credit (CREDIT) and the adoption of drought-resistant crops. The results indicate that having access to credit increases the likelihood of smallholder farmers adopting drought-resistant crops by a factor of 0.128. This implies that farmers who can access informal credit sources such as stokvels and formal credit from financial institutions are more likely to afford and cultivate drought-resistant crops. Given the capital-intensive nature of acquiring drought-resistant crops (i.e., improved crop cultivars), farmers with limited resources may face difficulties purchasing such crops without credit assistance. This finding highlights the important role of credit in facilitating climate change adaptation. These results align with previous studies (Ojo & Baiyegunhi, 2020; Chipfupa *et al*., 2021).

Table 7.4: Parameter Estimates of the MNL Climate Change Adaptation Model

Variable code	Planting drought-resistant crops		Shifting planting dates		Mixed farming		Irrigation	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
AGE	0.012	0.014	-0.000	0.015	-0.014	0.011	0.023	0.025
GENDER	-0.473	0.372	-1.305***	0.436	-0.440	0.308	-0.401	0.585
EDUCAT	0.080*	0.046	0.050	0.045	0.030	0.035	0.188**	0.094
LAND_SIZE	-0.128	0.183	0.024	0.176	0.181	0.147	0.030	0.259
MARKET_ACCESS	0.522	0.361	1.151***	0.390	1.046***	0.306	0.507	0.581
H_ADULTS	0.024	0.056	0.060	0.055	0.063	0.046	0.031	0.090
TLU	0.036*	0.018	0.035*	0.019	0.047***	0.016	0.021	0.028
CREDIT	1.548***	0.369	1.188***	0.371	0.427	0.292	1.940***	0.683
TOTAL_INCOME	5.61e-07	2.53e-06	6.24e-07	2.48e-06	1.57e-06	2.28e-06	1.75e-06	2.48e-06
EXTENSION	0.606	0.386	0.638*	0.386	0.243	0.391	0.158	0.677
Base category	No adaptation							
Number of observations	400							
LR Chi-square	124.80***							
Log likelihood	-517.58624							
Pseudo-R^2	0.1076							

Notes: ***, **, and * means significant at 1%, 5%, and 10% levels, respectively

Table 7.5: Marginal Effects from the MNL Climate Change Adaptation Model

Variable code	Planting drought-resistant crops		Shifting planting dates		Mixed farming		Irrigation	
	dy/dx	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**
AGE	0.002	0.001	0.000	0.002	-0.004**	0.002	0.001	0.001
GENDER	0.006	0.041	-0.124**	0.048	0.019	0.052	0.005	0.022
EDUCAT	0.006	0.006	0.001	0.005	-0.004	0.006	0.006	0.004
LAND_SIZE	-0.029	0.019	-0.004	0.016	0.044**	0.020	-0.000	0.009
MARKET_ACCESS	-0.031	0.039	0.064	0.042	0.114**	0.051	-0.009	0.022
H_ADULTS	-0.002	0.005	0.003	0.005	0.008	0.007	-0.000	0.003
TLU	0.001	0.002	0.000	0.002	0.005***	0.002	-0.000	0.001
CREDIT	0.128***	0.041	0.064*	0.039	-0.100**	0.047	0.050*	0.028
TOTAL_INCOME	-5.24e-08	2.00e-07	-4.63e-08	1.72e-07	2.37e-07	2.38e-07	3.92e-08	5.22e-08
EXTENSION	0.046*	0.026	0.047**	0.024	-0.025	0.054	-0.008	0.025

Notes: ***, **, and * means significant at 1%, 5%, and 10% levels, respectively.

7.4.2.2. Shifting Planting Dates

As elaborated earlier, approximately 17.25% of the smallholder farmers in the sample implemented shifting planting dates as a climate change adaptation strategy. The analysis reveals a positive and statistically significant ($p<0.05$) relationship between access to extension services (EXTENSION) and shifting planting dates. This finding aligns with the *a priori* expectation, as extension officers play a crucial role in advising smallholder farmers on the appropriate months for cultivation based on predicted or prevailing climatic conditions in the area. Access to extension services increases the probability of adopting shifting planting dates by a factor of 0.047. This result can be attributed to access to extension services enhancing smallholder farmers' access to climate-related information.

Consequently, farmers become more knowledgeable about the adverse impacts of climate change (Dinku *et al*., 2014) and the potential adaptation strategies that can be employed. Access to information enables farmers to make informed decisions regarding shifting planting dates to mitigate the adverse effects of climate change. These findings are consistent with the study conducted by Kibue *et al*. (2015), which found that farmers' willingness to adapt to climate change increases with improved access to extension services.

The analysis reveals a negative and statistically significant ($p<0.05$) relationship between gender (GENDER) and the adoption of shifting planting dates as a climate change adaptation strategy. This result suggests that female farmers are more likely to shift planting dates than their male counterparts. The probability of adopting moving planting dates increases by a factor of 0.124 for female farmers. This finding is consistent with previous studies conducted in Kenya (Pello *et al*., 2021) and South Africa (Thinda *et al*., 2020). The higher adaptive capability of female smallholder farmers may be attributed to their heightened vulnerability to climate change, arising from factors such as limited off-farm activities, lower levels of education, and weaker social networks (Djoudi *et al*., 2016). The observed gender disparity in adopting shifting planting dates highlights the need for targeted interventions and support for female farmers to enhance their resilience to climate change.

Access to credit (CREDIT) has a positive and statistically significant ($p<0.1$) relationship with the adoption of shifting planting dates as a climate change adaptation strategy. The probability of shifting planting dates increases by 0.064 when farmers have access to credit. Due to unpredictable climatic changes, farmers often plant summer crops later than usual, outside their region's optimum planting time. As a result, farmers might require financial resources to purchase early maturing crops. This finding underscores the importance of financial support mechanisms in promoting climate change adaptation in the agricultural sector.

7.4.2.3. Mixed Farming

The variable for the age of the household head (AGE) has a negative and statistically significant ($p<0.05$) relationship with the adoption of mixed farming as a climate change adaptation strategy. This suggests that older farmers are less likely to adopt mixed farming to adapt to climate change. The adoption of mixed farming decreases by 0.004 with increasing age. The negative impact of age on adopting mixed farming may stem from older farmers having limited knowledge about the benefits and practices associated with mixed farming, potentially due to lower levels of education. This finding implies that older farmers may be less aware of the available options and strategies suitable for their farms in the context of climate change. These findings align with the results from Ojo *et al*. (2021) who identified a negative and significant relationship between age and the adoption of climate change adaptation strategies in South Africa. Similarly, in Ghana, Zakaria *et al*. (2020) reported a negative and significant relationship between age and adopting climate change adaptation strategies. Overall, the results suggest that age can be an important factor influencing the adoption of specific climate change adaptation strategies, highlighting the need for targeted interventions and education programmes to increase the awareness and knowledge of older farmers regarding suitable adaptation practices.

The variable for land size (LAND_SIZE) has a positive and statistically significant ($p<0.05$) relationship with the adoption of mixed farming as a climate change adaptation strategy. This implies that as the land under cultivation increases by a hectare, the likelihood of adopting mixed farming as an adaptation strategy increases by 0.044. The positive relationship between land size and the adoption of mixed farming can be attributed to larger farm sizes' advantages. Farmers with larger land sizes can explore and integrate various agricultural enterprises, such as livestock, alongside their crop production. This diversification reduces the risks associated with climate change, as different enterprises can provide a buffer against the potential impacts of unpredictable weather patterns. The results suggest that farmers with larger land sizes have the flexibility and resources to implement mixed farming practices, which can enhance their resilience to climate change. These findings align with previous studies that have also demonstrated a positive relationship between land size and adopting climate change adaptation strategies (Ojo & Baiyegunhi, 2020; Bryan *et al*., 2013). Overall, the positive association between land size and the adoption of mixed farming highlights the importance of land resources in facilitating adaptive strategies. It emphasises the potential benefits of promoting larger land holdings or supporting farmers in utilising their available land more effectively to enhance climate resilience in agricultural systems.

The coefficient for market access (MARKET_ACCESS) has a positive and statistically significant ($P<0.05$) relationship with the adoption of mixed farming as a climate change adaptation strategy. The findings indicate that farmers with access to markets are more likely to adopt mixed farming practices to respond to climate change. The probability of adopting mixed farming increases by 0.114 with improved market access. The positive relationship between market access and adopting mixed farming can be attributed to several factors. Firstly, access to markets allows farmers to procure necessary farm inputs, such as improved seeds or livestock, enabling them to expand and diversify their agricultural activities. Secondly, farmers with market access can easily sell their cash crops or livestock, enhancing their income and financial capacity to invest in mixed farming. This income can contribute to the necessary resources and flexibility for implementing mixed farming practices. These results align with previous studies that identified a positive association between market access and climate change adaptation (Alemayehu & Bewket, 2017; Adimassu & Kessler, 2016). Improving market connectivity and ensuring farmers have access to reliable markets can enhance their capacity to diversify their agricultural activities and improve their resilience to climate variability. Access to markets can empower farmers to make informed decisions, access necessary resources, and capitalise on market opportunities, ultimately enhancing their adaptive capacity in the face of climate change.

The results show that there is a positive and statistically significant ($p<0.01$) relationship between livestock ownership (TLU) and the adoption of mixed farming as a climate change adaptation strategy. An increase in livestock ownership increases the probability of adopting mixed farming by a factor of 0.005. The observed positive relationship can be attributed to the benefits of livestock ownership in diversifying smallholder farmers' agricultural activities. Livestock serves as an additional enterprise alongside crop farming, enabling farmers to mitigate risks associated with unfavourable climatic conditions and potential crop failures. Farmers can spread their risks by incorporating livestock into their farming systems and enhance their resilience to climate change impacts. The findings of this study are consistent with other empirical studies that highlighted the positive association between livestock ownership and climate change adaptation (Amare & Simane, 2017; Regmi, Dhakal & Ghimire, 2017). These studies have emphasised the role of livestock in providing alternative sources of income, nutrient-rich manure for soil fertility and potential insurance against crop losses, all of which contribute to farmers' ability to adapt to changing climatic conditions. In addition, the positive relationship between livestock ownership and the adoption of mixed farming underscores the importance of integrating livestock in climate change adaptation strategies. Encouraging and supporting smallholder farmers in livestock rearing can enhance their adaptive capacity, diversify their income sources, and promote sustainable farming practices. Such efforts can build resilience and reduce vulnerability in the face of climate change challenges.

Contrary to the *a priori* expectation, access to credit (CREDIT) has a negative and statistically significant ($p<0.05$) relationship with the adoption of mixed farming as a climate change adaptation strategy. This finding suggests that farmers with access to credit is less likely to diversify their farming enterprises. With all other variables held constant, access to credit decreases the probability of adopting mixed farming by a factor of 0.1. The unexpected adverse effect of credit on mixed farming adoption could be attributed to specific circumstances surrounding credit availability and utilisation in the study area. Focus group discussions revealed that the credit sources for farmers practising mixed farming predominantly stem from informal lending institutions, which tend to impose high-interest rates. These exorbitant interest rates may discourage farmers from investing in diverse farming enterprises like mixed farming, as the financial burden becomes a disincentive for pursuing such practices. The findings underscore the significance of considering the presence of credit and its accessibility and affordability. While access to credit is generally perceived as a facilitator of agricultural activities, the specific terms and conditions associated with credit sources can significantly influence farmers' decisions and behaviours. In this context, the high interest rates charged by informal lending institutions appear to hinder farmers' inclination towards adopting mixed farming. This result highlights the importance of promoting affordable and accessible credit options for farmers practising climate change adaptation strategies like mixed farming. Creating favourable credit environments that offer reasonable interest rates and flexible repayment terms could encourage farmers to embrace diverse farming enterprises, contributing to their resilience to climate change.

7.4.2.4. Irrigation

The results indicate that access to credit (CREDIT) has a positive and statistically significant ($p<0.1$) effect on the adoption of irrigation as a climate change adaptation strategy. Access to credit increases the probability of adopting irrigation by a factor of 0.05. This finding highlights the importance of credit in facilitating the adoption of irrigation, considering its capital-intensive nature. Implementing irrigation systems, which involve acquiring infrastructure such as tanks and pipes, requires substantial financial resources that may not be readily available to smallholder farmers. By providing access to credit, farmers gain additional financial resources to purchase the necessary irrigation infrastructure. This financial support is crucial in overcoming the financial barriers associated with implementing irrigation as a climate change adaptation strategy. Even if farmers possess the necessary information and knowledge about climate change and its impacts, their ability to acquire the required equipment may be constrained if they lack access to credit. These findings align with previous empirical studies (Ojo & Baiyegunhi, 2020), further emphasising the significance of credit in facilitating the adoption of climate change adaptation strategies, specifically in irrigation. Access to credit provides farmers with the means to invest in necessary infrastructure and empowers them to manage water resources better and enhance their agricultural productivity and resilience.

7.5. SUMMARY

This chapter has assessed the determinants of farmers' choice of climate change adaptation strategies. The MNL model was used to analyse the determinants of farmers' choices of climate adaptation strategies. Various demographic, socioeconomic and institutional variables were considered for the MNL model. In the MNL model, the farmers' adaptation strategies serve as the dependent variables, and the results are interpreted using marginal effects, which indicate the expected change in the probability of adopting a particular adaptation choice.

The study's findings revealed that smallholder farmers in the study area had implemented diverse adaptation strategies to cope with climate change. Descriptive statistics showed that mixed farming, shifting planting dates, planting drought-resistant crops, and irrigation are among the methods employed by farmers. However, specific barriers, such as lack of information, insufficient financial resources and limited land and labour, hinder their adaptation efforts. Interestingly, access to credit does not appear to be a significant challenge in the study area, as farmers rely on informal credit sources to support their agricultural activities.

Most smallholder farmers in the study area are female, making them particularly vulnerable to the adverse effects of climate change. The low access to extension services further exacerbates the situation, impeding the transfer of crucial agricultural information and innovative practices that could mitigate climate change impacts. Consequently, it is unsurprising that farmers identify a lack of information as a barrier to adaptation. The results of the MNL marginal analysis revealed that access to credit, access to extension services, gender of the household head (specifically female headship), market access, TLUs, and land size significantly influence farmers' choice of adaptation strategies. It is crucial to address financial constraints, expand the reach of extension services and promote mixed farming approaches that integrate livestock systems with cropping systems to enhance the adaptive capacity of smallholder farmers. Farmers can enhance their resilience and effectively adapt to climate change by addressing these factors.

CHAPTER 8: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1. SUMMARY

Agricultural production remains an important livelihood strategy for most smallholder farmers situated in the former homeland areas of South Africa. It is widely acknowledged in the literature that climate change has exacerbated the challenges faced by farmers in the study. The South African government recognises agriculture as a potential pathway to alleviate poverty among rural households. However, the impacts of climate change and its variability pose significant threats to the sustainability of rural livelihoods, potentially hindering the government's poverty eradication efforts. One approach to mitigating the adverse effects of climate change on agriculture is through adaptation. Climate change adaptation is a multifaceted process that requires farmers first to recognise the changing climate and then act by implementing adaptation strategies on their farming practices.

While numerous studies have examined climate change perceptions and adaptation in South Africa, very few have focused explicitly on the uMkhanyakude district in the KwaZulu-Natal province. Moreover, there was a need to conduct local level analysis of the impacts of climate change on local people because of two main reasons. Firstly, farmers' livelihoods tend to differ across regions because of the ecological orientation of the regions. Secondly, regional climatic variations mean that the impact of climate change would be experienced differently across areas in the same region. The differences in climatic variations in the same region show the need for local studies on the perception and impact of climate change on the livelihoods of farmers. An understanding of the adverse effects of climate change on the livelihoods of rural people is crucial in the design of appropriate climate change policies.

This study was conducted in the uMkhanyakude district of KwaZulu-Natal. Out of 11 districts in KwaZulu-Natal, uMkhanyakude was purposively chosen because one of the poorest and most arid districts. Therefore, the current study was motivated by investigating the perceptions and climate change adaptation strategies employed by smallholder farmers and their underlying determinants. The specific objectives of the study were to:

i. Examine perceptions of smallholder farmers on climate change using information from smallholder farmers over a 20-year (1999-2019) production season.
ii. Identify socioeconomic determinants of smallholder farmers' perceptions of climate change.
iii. Determine the perceived impact of climate change on smallholder farmers' livelihoods.

iv. Analyse the determinants of smallholder farmers' choice of adaptation strategies.

This study used a mixed-method approach in data collection and analysis to achieve the specific objectives. All the objectives were empirically investigated using primary data from the survey and focus group discussions.

8.1.1. Perceptions of Farmers in the uMkhanyakude District

Principal component analysis (PCA) was used to analyse the dominant perceptions of climate change among farmers in the uMkhanyakude district; this was conducted to address the first objective of the study. The results in Chapter 4 revealed that farmers' perceptions could be grouped into a) natural disasters (drought and floods); b) institutional support (access to training and extension services); c) decrease in crop yields and loss of assets; d) changes in temperature and rainfall and e) poor livestock production and access to extension on climate change (access to climate change information). Farmers generally perceived that summer temperatures had increased while summer season rainfall had decreased over the reference period. Farmers also perceived frequent drought occurrence in the uMkhanyakude district.

8.1.2. Socioeconomic Determinants of Smallholder Farmers' Perceptions of Climate Change

To address the second objective, Chapter 5 used a binary logistic model to examine the socioeconomic factors influencing farmers' perceptions of climate change. The findings indicated that several factors significantly impacted farmers' perceptions, including access to extension services on climate change, the gender of the household head, access to radio/TV, training, and membership in farmers' associations. Descriptive statistics revealed that older farmers perceived climate change. Climate change perceivers had larger plot sizes and lived further from tarred roads. It was also evident that farmers had limited access to extension services for both climate change perceivers and non-perceivers.

8.1.3. Perceived Impact of Climate Change on Smallholder Farmers' Livelihoods

In Chapter 6, the study employed the Sustainable Livelihood Framework to assess the perceived impact of climate change on the livelihoods of smallholder farmers. The findings indicated that climate change had significantly affected the livelihood assets that smallholder farmers relied on for their livelihood. Specifically, drought had emerged as a prominent challenge in the uMkhanyakude district. The prolonged periods of drought had reduced crop and livestock production, forcing households to heavily rely on food purchases. In addition, findings indicated that climate change had caused a decline in forest resources, adversely affecting the income-generating opportunities associated with these resources for the households in the study.

8.1.4. Determinants of Smallholder Farmers' Choice of Climate Change Adaptation Strategies

In Chapter 7, this study examined climate change adaptation strategies and their underlying determinants. The descriptive statistics analysis highlighted that smallholder farmers in the study area had been implementing various adaptation measures in response to climate change. These measures included irrigation, mixed farming, drought-resistant crops and shifting planting dates. Farmers who had not adopted any adaptation method mentioned barriers such as lack of information, inadequate financial resources, and labour shortages. The study employed the MNL model to identify the factors influencing farmers' choice of adaptation strategies. The results of the MNL model revealed that several factors played a significant role in determining farmers' adaptation methods. These factors included access to extension services, gender of the household head (specifically female headship), access to credit, market access, TLUs and land size. Notably, access to credit was a primary driver influencing adopting adaptation strategies across all four categories.

8.2. CONCLUSIONS

The empirical analysis in this study was based on data obtained from a farm household survey conducted in two local municipalities within the uMkhanyakude district. The findings presented in Chapter 4 indicated that most smallholder farmers involved in farming were women, highlighting the significance of considering gender in climate change policies. Moreover, most farmers in the uMkhanyakude district perceived climate change. The dominant farmers' perceptions were grouped into changes in rainfall and temperature; natural disasters; , institutional support; , decrease in crop yields and loss of assets, poor livestock production, and access to extension services on climate change (access to information). The assessment of farmers' perceptions reveals the variability in how climate change is perceived among farmers, emphasising the need to account for specific local contexts. Farmers generally perceived a decline in summer rainfall and an increase in summer temperatures, aligning with existing empirical literature that suggests a warming trend on Earth. These results reinforce the implications of climate change for the future of farming, particularly for smallholder farmers who face resource constraints.

The findings from the binary logit model in Chapter 5 revealed that climate change perceptions in the study area were influenced by various factors, including the age and education level of the household head, membership in farmers' associations, size of land holding, adult equivalents and access to irrigation. Notably, most climate change perceivers were women, which aligns with existing empirical evidence highlighting the pivotal role of women as primary food producers in rural areas. In addition, climate change perceivers are slightly older than non-perceivers, suggesting that age, as a proxy for farming experience, plays a vital role in perceiving climate change.

The findings presented in Chapter 6 highlighted farmers' reliance on various livelihood assets, including natural, physical, financial, and social capital. The livelihoods in the study area predominantly rely on a rainfed agricultural system, which is highly vulnerable to the adverse impacts of climate change. Climate change has significantly eroded the livelihood assets that farmers depend on, posing a tangible threat to the well-being of smallholder farmers. Persistent drought has diminished crop and livestock production, compelling households to depend heavily on food purchases. These findings underscore the urgent need for effective climate change adaptation strategies to safeguard the livelihoods of smallholder farmers in the face of climate change.

The findings presented in Chapter 7 indicated that farmers in the study area have actively adopted climate change adaptation strategies to mitigate the adverse effects of climate change. Among these strategies, mixed farming was the most used approach. However, a significant obstacle to effective adaptation was the lack of information highlighting the importance of access to relevant knowledge and resources. The study also revealed that smallholder farmers had limited access to extension services, which hindered the transfer of agricultural information to smallholder farmers. The results obtained from the MNL model demonstrated that access to credit was central in driving climate change adaptation among farmers. In addition, factors such as access to extension services, market accessibility, gender of the household head, age of the household head, land size, and TLUs were identified as facilitating factors for climate change adaptation. These findings emphasise the significance of addressing financial constraints, improving access to extension services, and considering gender dynamics in developing effective climate change adaptation strategies for smallholder farmers.

8.3. RECOMMENDATIONS

The findings of this study offer valuable insights for evidence-based policymaking concerning climate change adaptation at both provincial and national government levels. The study recommends the following;

8.3.1. Improved Communication Strategies

The analysis of farmers' climate change perceptions, as presented in Chapter 4, highlights the importance of recognising the location-specific nature of these perceptions. This underscores the need to customise climate risk messaging to specific regions, ensuring the effectiveness of climate risk communication strategies. It is worth noting that, on average, farmers in the study area had educational attainment up to the 7^{th} grade. Therefore, it is important to package climate change information that is easily understandable to farmers, minimising cognitive effort and enhancing comprehension. By considering these factors, policymakers can improve the accessibility and relevance of climate change information, empowering farmers to make informed decisions and take appropriate adaptation actions.

8.3.2. Gender Mainstreaming

Given that women constitute most smallholder farmers who both perceive climate change and actively engage in farming, policymakers must prioritise gender mainstreaming in the design and implementation of climate change extension interventions. Recognising the unique challenges and opportunities female farmers face can lead to more targeted and effective climate change adaptation and mitigation strategies.

8.3.3. Access to Extension Services

In addition, the significant proportion of smallholder farmers who did not receive extension services between August 2019 and August 2020 highlights the urgent need to enhance agricultural support in rural areas. By improving access to extension services, policymakers can ensure that farmers receive the necessary knowledge, resources, and guidance to effectively cope with the challenges posed by climate change and enhance their resilience.

8.3.4. Institutional Arrangements

The findings in Chapter 5 highlight the significant influence of institutional arrangements (membership in farmers organizations). Therefore, it is recommended that these institutional arrangements should be strengthened and expanded to ensure that the majority of farmers benefit from such institutions. In addition to traditional extension visits, leveraging mass media channels like community radio stations and television can effectively disseminate climate change information. Delivering climate change-related information in local languages is advisable to enhance communication effectiveness, enabling better understanding and engagement among the farming community. By adopting these strategies, policymakers can facilitate improved access to climate change information and promote effective communication between experts and farmers.

8.3.5. Income Diversification

Regarding the impact of climate change on farmers' livelihoods, the findings in Chapter 6 indicate that smallholder farmers need a range of capital assets to build resilience against the adverse effects of climate change. Considering this, it is recommended that rural extension services and locally-based NGOs prioritise enhancing alternative livelihood strategies to diversify farm income. By promoting and supporting the adoption of diversified income sources, farmers can reduce their vulnerability to climate change-related risks and enhance their overall resilience. This approach will contribute to the long-term sustainability of smallholder farming communities and help them adapt to the changing climate.

8.3.6. Mixed Farming

The findings in Chapter 7 regarding farmers' choice of adaptation strategies have significant policy implications for enhancing local climate change resilience strategies. It is recommended that the local department of agriculture, specifically animal health and extension services, along with locally-based NGO’s, promote and encourage the adoption of mixed farming as a climate resilience strategy. This approach will help diversify livelihoods, providing farmers with insurance in case one farming system is affected by climate change impacts.

8.3.7. Improve Access to Credit

In addition, the MNL model results emphasise the importance of access to credit in facilitating farmers’ adaptation to climate change. Therefore, programmes and initiatives to support smallholder farmers should prioritise efforts to facilitate their access to both formal and informal sources of credit. By addressing these key factors, policymakers can contribute to building the adaptive capacity of farmers and strengthening their ability to cope with climate change challenges.

8.4. STUDY LIMITATIONS AND AREAS OF FURTHER RESEARCH

A limitation of this study is its reliance on cross-sectional data, which could be addressed by utilising panel data. The use of seasonal data in this study may lead to a potential bias as farmers may emphasise recent climatic events more than the broader historical context. Therefore, future studies can collect data over multiple seasons and employ robust panel data methods to assess the long-term impact of climate change on smallholder farming systems. Adopting such an approach can provide a more comprehensive and accurate understanding of the relationship between climate change and smallholder agriculture.

The PCA results on dominant farmers' perceptions give a starting point for understanding climate change perceptions in the uMkhanyakude district. However, these perceptions may be influenced by cultural and socio-psychological factors. Given that this study relied on environmental factors as a proxy for farmers' perceptions, it might be beneficial to use behavioural approaches in understanding farmers' perceptions.

Further research can focus on quantifying the costs and benefits of adapting to climate change in smallholder farming systems. This will give a snapshot of the potential benefits or losses that can accrue when adopting adaptation strategies.

The results of the MNL model revealed that access to credit is an important determinant influencing climate change adaptation across various adaptation measures. Most smallholder farmers in South Africa reside in marginalised locations and face financial constraints that hinder their ability to adapt effectively to climate change. Therefore, it is crucial to conduct further research to explore the effectiveness of traditional knowledge systems in climate change adaptation within smallholder farming systems. Traditional knowledge systems, passed down through generations, may offer valuable strategies that do not rely on financial resources, making them particularly relevant for resource-limited farmers. Investigating the role of traditional knowledge systems can contribute to a comprehensive understanding of climate change adaptation and provide alternative pathways for smallholder farmers to build resilience.

This study found that women constitute most smallholder farmers, making them susceptible to the adverse effects of climate change. Therefore, it is essential to conduct a gendered analysis to comprehensively understand how climate change affects the livelihoods of female smallholder farmers. Such an analysis would delve into the specific challenges, needs, and opportunities women face in adapting to and mitigating the negative impacts of climate change. By examining the gender dimensions of climate change, policymakers and practitioners can develop targeted interventions and strategies that address female smallholder farmers' unique circumstances and concerns, ultimately fostering more inclusive and sustainable agricultural practices.

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APPENDIX A: SURVEY QUESTIONNAIRE

Introduction
My name is………………………………………………………………. I am from the University of the Free State. The university is conducting research in KwaZulu-Natal that is looking **at Smallholder farmers' perception and adaptation to climate change: a case of uMkhanyakude district in KwaZulu-Natal province of South Africa.** There are no wrong and right answers to these questions. I would like to assure you that all the information provided here will be treated as **STRICTLY CONFIDENTIAL and** will be used for academic purposes only. Interview will take about 45 minutes.

Identification

Interviewer name		**Date of interview**	
Local Municipality			

Codes: 1= Jozini 2= UMhlabuyalingana

Section A: Household demographics
A1. What is the total number of your household members? Please complete table below (*Record household head* details in the first row*).

Household member ID	Position in the household	Age	Gender	Marital status	Education level	Main occupation

<u>Key</u>

<u>Household position</u> *1=Household head** *2=Spouse* *3=Daughter or son* *4=Other (specify e.g., cousin)*	*<u>Gender</u>* *1= Male* *0=Female*	*<u>Marital status</u>* *1=Single* *2=Married* *3=Divorced* *4=Widowed* *5=Cohabitation*	*<u>Main occupation</u>* *1=Fulltime farmer* *2=Regular salaried job* *3=Temporary job (specify)* *4=Unemployed* *5=Self employed* *6=Student* *7=Retired* *8=Other*

** Household head refers to the <u>de facto</u> household head that stays in the household for 4 or more days per week*

A2 What is the total number of your household members		
A3 How many of the household members are adults (18years old or more)?		
A4 How many of the household members are children (less than 18? years old)?		
A5 How many of the adult household members cannot work because of chronic sickness or old age?		
A6 How many of the household members are employed?	Permanently employed	
	Temporarily employed	

A7 What is the household's main religion? No religion=0 Traditional=1 Christian=2 Nazareth=3 Other (Specify)⋯=3	

Section B: Farming activities and land holding

B1 Are you involved in any crop or livestock farming activity? 1=Yes 0= No	
B2 If Yes in B1, Is the head of the household involved in farming full-time? 1=Yes 0= No	
B3 Is any other member of the household involved in farming activities? 1=Yes 0= No	
B4 How many household members help with or are involved in farming regularly?	

B5 If Yes in B1, what farming activities is your household involved in and what is the main purpose of the farming activity? (*Complete table below*)

Farming activity	Tick	Experience (number of years)	Main purpose: 1=Main source of food 2=Extra source of food 3=Main source of income 4= Extra source of income 5=Leisure activity / hobby 6=Other (specify)
Crop production			
Vegetable production			
Community gardens			
Livestock production			
Other (specify)			

B6 What is the total size in hectares of land your household has access to?	ha
B7 How do you feel about your land size? 1=Too small 2=Just right 3=Too large	
B8 Rate the quality of your land for crop production 0=Poor 1=Average 2=Good	
B9 How did you acquire the land? 1=Allocated by traditional leader (*Inkosi*) 2=Inherited 3=Leasing/ renting 4=Bought 5=Other =5 (*Specify………)*	
B10 What is the land size in hectares?	ha
B11 Are you satisfied with the present tenure security of your land? Yes=1 No=0	
B12 Are you permitted to sell or rent your piece of land? Yes=1 No=0	
B13 How do you feel about the rainfall distribution for crop production since August 2013? 0= Very Poor 1=Poor 2= Average 3=Good 4=Very good	
B14 How long have you been farming?	years
B15 What type of agriculture do you practice? 1=Rain-fed 2=Irrigated 3=Mixed	

Section C: Sources of income

Source of household income	**Amount per given time (R)**	**How often? (e.g. monthly, daily; weekly; bi-weekly)**	**Number of times in the past 12 months**	**Total amount**
Remittances				
Arts and craft				

Permanent employment				
Temporary/casual employment				
Hawking/petty trading				
Crop farming				
Livestock farming				
Other (specify)				

C1 Are any of your household members receiving government grants? Yes=1 No=0		
C2 If yes on C1, how many are on the:	Old age grant?	
	Child support grant?	
	Disability grant?	
	Foster child grant?	
	Care Dependency grant?	
C3 How much money is spent on food items per month?		**R**
C4 Taking all means* into consideration, how would you describe your household food consumption since August 2019? 1=Frequent food shortages throughout the year 2= Occasional food shortages 3=No food shortages, no surplus 4=Food surplus		

All means include: own production + food purchases + help from different sources + food hunted from forest, lakes, etc.

Section D: Assets ownership
Do you own the following assets?

Asset	**No.**	**Asset Value (R)**	**Asset**	**No.**	**Asset Value (R)**	**Asset**	**No.**	**Asset value**
Block, tile house			Car			cell phone		
Block, zinc house			Motorcycle			TV		
Round, thatch house			bicycle			Radio		
Round pole and mud or shack house			tractor			Mouldboard plough		
Tap			hoe			Knapsack sprayer		
Borehole			spades			Ripper		
Protected well			wheelbarrow			Disc harrows		
Water tank			telephone			Disc plough		
Trailers			Rotary slashers			Ridgers		

Cultivators			Fertilizer spreaders			Wheat drills		
Harvesters			Other (Specify)			Other (Specify)		

Section D: Livestock ownership

Type	Goats/sheep	Cattle	Horse	Donkey	Pigs	Chicken/ducks/turkeys
Current herd size						

Section E: Institutions and support services

E1 Please indicate if you are a member of these groups and your level of decision making

Group	**Yes=1 No=0**	**Level of decision making Low=1Moderate=2 High=3**
Farmer association		
Marketing co-operative or group		
Water user association		
Credit and savings group (stokvel)		
Local governance		
Traditional/tribal authority		
Other (specify)		

E2 Did you use any credit or loan facility since August 2019? Yes=1 No=0	
E3 If yes in E2, what was the main source of the credit/loan? Relative or friend=1 Money lender=2 Savings club (stokvel)=3 Input supplier=4 Financial institution=5 (Specify name of financial institution…….) Output buyer =6 Other=7(Specify……..)	
E4 What was the purpose of the loan/credit? Family emergency=1 Agricultural purposes=2 Both=3 Other (specify….)=4	
E5 Were you able to pay back the loan/credit in time? Yes=1 No=0	
E6 Did you receive funding or any other sources of credit support from government since August 2019? Yes=1 No=0	
E7 If yes in E6, how often do you receive the funding or credit for farming activities? Never=0 Sometimes=1 Always=2	
E8 Did you have any contact with extension officer since May 2019? Yes=1 No=0	
E9 If yes in E8, how often did you contact extension officers? Never=0 Sometimes=1 Always=2	
E10 If yes on E8, did you invite the extension officer? Yes=1 No=0	
E11 Are the extension officers from: 1=Government/ parastatal? 2=Non-governmental organisation (NGO)? 3=Private company?	
E12 What is the distance to the extension office?	
E13 Did you or a member of your household receive any training from government or any other organization? Yes=1 No=0	
E14 If yes on E13, please specify the training provided……………………	
E15 How would you describe the usefulness of the training received in farming? Not useful at all=1 somewhat useful=2 Useful=3 Very useful=4	

E16 Do you have access and use improved production inputs and technologies? Yes=1 No=0	
E17 If yes in E16, what is the distance to the nearest farm input shop?	km
E18 Do you have access to markets? Yes=1 No=0	

E18 Do you use the following sources of agricultural information?

Source of information	**Yes=1 No=0**	**Source of information**	**Yes=1 No=0**
Extension workers		Newspaper	
Radio/television		Internet	
Other farmers		Other (specify….)	
Cell phones/SMS			

E19 What is your main source of farming information 0=None 1=Radio/television 2=Extension officer 3=Cell phone/SMS 4=Internet 5=Newspaper 6=Other farmers 7=Other (specify)	
E20 Do you understand the information disseminated by the main information source in E18? Not at all=0 Somewhat=1 Absolutely=2	
E21 Do you receive information on climate change through extension services? Yes=1 No=0	
E22 How long have you been living in this community?	years
E23 How many people in this community can you revert to in case of need?	
E24 Generally, are people in this community trustworthy? (1= don't trust anyone, 2= the majority are not trustworthy, 3=the majority are trustworthy, 4=everyone is trustworthy)	

Section F: Access to infrastructure

Infrastructure	Spaza shops	Tarred road	School	Health clinic	Water pipe	Electricity poles	River/dam
Walking distance (in km) to the nearest							

Section G: Climate change perceptions

G1 In general, do you believe that climate change, i.e. "abnormal" trends in the normal climate variability, is occurring?................. (Yes=1 No=0)	
G2 What do you think is the reason behind the change? 1= Land use/land cover change, 2=Carbon emission, 3=Volcanoes, 4=God, 5=Other… (specify))	
G3 Have you noticed any long-term changes in the mean temperature over the last 20 years? 1=yes 0=no. If yes, proceed to G4.	
G4 Summer season temperature. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G5 Winter season temperature. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G6 Length of cold periods. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G7 Length of hot periods. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	

G8 Have you noticed any long -term changes in the mean rainfall over the last 20 years? 1=yes 0=no. If yes, proceed to G9.	
G9 Summer season rainfall. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G10 Winter season rainfall. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G11 Length of summer season rainfall. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G12 Length of winter season rainfall. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G13 Fluctuation in timing of rains. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G14 Frequency of droughts. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G15 Frequency of floods. 1=Increased 2=Decreased 3=Stayed the same 4= I don't know	
G16 Strong wind. 1=Increased 2=Decreased 3=stayed the same 4= I don't know	
G17 In general, what is your feeling about climate change: 1=I have no particular feeling about climate change, 2=Climate change is somehow bad, 3= Climate change is very bad	

Section H: Climate change adaptation

H1 Have you carried out any adaptation measures? Yes=1 No=0. If yes, pleases indicate if you have carried out the following adaptation strategies	
H2 Used drought resistant crop varieties. Yes=1 No=0.	
H3 Used improved crop varieties. Yes=1 No=0.	
H4 Implement soil conservation. Yes=1 No=0.	
H5 Plant trees for shading. Yes=1 No=0.	
H6 Shift planting dates. Yes=1 No=0.	
H7 Build a water harvesting scheme or started irrigating crops. Yes=1 No=0.	
H8 Implemented mixed farming (crop and livestock). Yes=1 No=0.	
H9 Implemented intercropping. Yes=1 No=0.	
H10 Implemented Mulching. Yes=1 No=0.	
H11 Lease out land. Yes=1 No=0.	
H12 Purchase insurance. Yes=1 No=0.	
H13 Implemented minimum tillage. Yes=1 No=0.	
H14 Implemented crop residue management. Yes=1 No=0.	

Section I: Barriers to adaptation

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

I1 I cannot adapt to climate change because I lack money. 1=Yes 0= No	
I2 I cannot adapt to climate change because I have a shortage of labour. 1=Yes 0= No	
I3 I cannot adapt to climate change because I lack climate related information. 1=Yes 0= No	
I4 I cannot adapt to climate change because there is poor potential for irrigation on my farmland. 1=Yes 0= No	
I5 I cannot adapt to climate change because there is shortage of land. 1=Yes 0= No	

I6 Do not know what to do. 1=Yes 0= No	

Section J: Behavioural decision making on climate change

Attitudes towards climate change	
J1 Climate change damages the natural environment and livestock in my village. 1=Yes 0= No	
J2 The environment in my village is in danger because of climate change. 1=Yes 0= No	
J3 I am willing to use my financial resources to reduce the impact of climate change. 1=Yes 0= No	
Subjective Norms	
J4 My family/peers often discuss climate change or global warming. 1=Yes 0= No	
J5 I would feel guilty if climate change had a negative impact in my village. 1=Yes 0= No	
J6 People should do everything they can to reduce the impact of climate change in my village. 1=Yes 0= No	
J7 I feel personally obliged to help reduce the impact of climate change in my village. 1=Yes 0= No	
J8 I feel adaptation to climate change is necessary for all of us. 1=Yes 0= No	
Perceived Behavioural Control	
J9 If everyone acts, we could reduce the impact of climate change in my village. 1=Yes 0= No	
J10 I have the ability to reduce the impact of climate change in my village. 1=Yes 0= No	
J11 I am confident that I could contribute to reduce the impact of climate change. 1=Yes 0= No	
J12 I am able to contribute to reduce carbon dioxide emission through adaptation. 1=Yes 0= No	
J13 I am able to contribute to reduce greenhouse gas emission through adaptation. 1=Yes 0= No	
Behavioural Intention	
J14 I am not willing to change my lifestyle to counteract global warming and climate change. 1=Yes 0= No	
J15 I am willing to implement pro-environmental methods for my peers. 1=Yes 0= No	
J16 It is my responsibility to encourage my neighbours to adopt climate change adaptation strategies. 1=Yes 0= No	
J17 I have made major efforts to adopt climate change adaptation strategies last year. 1=Yes 0= No	
J18 I am willing to implement pro-environmental methods for my family. 1=Yes 0= No	
J19 I'll do everything that I can to reduce the impact of climate change. 1=Yes 0= No	

Section K: Psychological capital

How important is the following values to you?

Social values	Very opposed to my values (1)	Somehow opposed to my values (2)	Neutral/Not an important value (3)	Somewhat an important value (4)	Very an important value (5)
Egalitarianism					
Equal rights					
Affirmative action					
Equal opportunities					
Equal wealth distribution					
Individualism					
Virtues of self-reliance					
Value of personal independence					
Precedence of individual interest over the social interests					
Moral worth of individual					
Hierarchism					
Top-down management					
Authority of hierarchy					
Patriarchy					
Technocracy					
Fatalism					
Powerlessness to influence the future due to uncertainty Lack of control over one's life					
Inevitability or predetermination of events					

Section L: Impact of climate change on livelihoods

What has been the impact of climate change on your livelihood? Yes- 1; No =0

Problem	Yes	No	Problem	Yes	No
Crop failure			Recurrent floods		

Poor livestock productivity			Loss of income		
Loss of livestock due to drought			Dwindling wild fruits and vegetation		
Loss of pasture land			Drying of streams and rivers		
Loss of agricultural land			Severe soil erosion		
Recurrent drought			Loss of assets due to floods and heavy winds		
Other, specify			Decrease in crop yield		

Section M: Household food insecurity access:

M1 In the past four weeks, did you worry that your household would not have enough food?	Yes/No	How often did this happen?*
M2 In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred (e.g. meat, fish, etc) because of a lack of resources (i.e. no means through either purchasing or growing it)?		
M3 In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?		
M4 In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat (e.g. porridge without sugar) because of a lack of resources to obtain other types of food?		
M5 In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?		
M6 In the past four weeks, did you or any other household member have to eat fewer meals in a day (normal is three meals a day) because there was not enough food?		
M7 In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?		
M8 In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?		
M9 In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?		

* 1 = Rarely (once or twice in the past four weeks); 2 = Sometimes (three to ten times in the past four weeks); 3 = Often (more than ten times in the past four weeks)

***************** THANK YOU**********

APPENDIX B: FOCUS GROUP GUIDE

1. What visible changes have you observed as related to rainfall, temperature, soil fertility, wildlife, crop productivity, livestock productivity, flow of streams, occurrence of floods, incidence of drought, forest vegetation cover, river/stream flow etc occurring in in the last twenty years in the village?
2. Have you heard of "climate change"? If yes from which sources?
3. How has been the trend of the rainfall and the temperature during the past 20 to 30 years? Is it increasing, decreasing, coming on time and stopping at the right time?
4. Can you tell us the sowing time of common grown crops some twenty-thirty years back and what time of the year do you practice seed sowing in recent years?
5. What coping and adaptation strategies have community members crafted to alleviate problems arising as a result of climatic variability
6. What effect has climate change inflicted on the livelihood of the local people (reflect on natural, physical, financial, human and social capital)?
7. What development interventions are carried out in the village to avert the impact of climate change? (Afforestation, water harvesting, irrigation, soil and water conservation, off farm employment, etc.
8. Do farmers have strong organizational arrangement that could enhance local development and social cohesion? Please give your opinion.
9. What should the government and community do to alleviate the impact of climate change in the community?

APPENDIX C: KEY INFORMANT GUIDE

Interview guide for Key Informants (extension officers, local NGOs and Ward Councillors)

Study topic: Smallholder farmers' perception and adaptation to climate change: a case of uMkhanyakude district in KwaZulu-Natal province of South Africa

1. What do you understand about climate change and variability?
2. What are the indicators of climate change occurrence in the community?
3. Is climate change an important agenda for the KwaZulu-Natal Department of Agriculture or the NGO/municipality you work for? If yes what are the development interventions introduced in the uMkhanyakude district municipality?
4. Are climate change development interventions appreciated and taken up by the community?
5. Do you think that farmers are aware of climate change and variability in their communities? If yes how did they acquire climate change information?
6. What coping mechanisms do farmers use to mitigate the negative effects of climate change? What are some of the adaptation strategies employed by farmers?
7. What difficulties do framers face when implementing climate change adaptation strategies?
8. What are some of the negative effects of climate change on local people livelihoods and food security?
9. In the community, how integrated are government institutions working on activities that are deemed helpful to avert the negative effects of climate change?
10. What are the challenges faced by the extension services and NGOs in trying to address climate change issues?
11. What are some of the farmers success stories that you have observed in relation to climate change adaptation?

APPENDIX D: PARTICIPANT CONSENT FORM

TITLE OF RESEARCH PROJECT

Smallholder farmers' perception and adaptation to climate change: a case of uMkhanyakude district in KwaZulu-Natal province of South Africa

Dear Mr/Mrs/Miss/Ms……………………………………… Date..…/..……/20.......

NATURE AND PURPOSE OF THE STUDY

The purpose of this research project is to study smallholder farmers' perception and climate change adaptation by small scale farmers in the uMkhanyakude district of KwaZulu-Natal, South Africa. This research is conducted by Mbongeni Maziya, a PhD student in the Centre for Sustainable Agriculture at the University of the Free State.

RESEARCH PROCESS

1. During the survey enumerators will ask questions and fill the questionnaire of the respondent.
2. The questionnaire is divided into 13 sections. We will ask you questions about your household, land holding, assets, income sources, climate change perception and adaptation, barriers to climate change adaptation, behavioural decision making and food security
3. The questionnaire is expected to last for 45 minutes.
4. During the focus group discussion, we will have 12 participants and will ask them nine questions. These questions are centred around climate change perception and adaptation, effect of climate change on livelihoods, sources of information, and interventions that can be implemented to avert the negative impact of climate change.
5. The focus group discussion is expected to last for an hour.

NOTIFICATION THAT PHOTOGRAPHIC MATERIAL AND TAPE RECORDINGS WILL BE REQUIRED

We will keep information collected from this study for future use on other studies on climate change adaptation. Your information will not contain your name and will be protected in a locked file. We will also require permission from the Research Ethics Committee before releasing the information.

CONFIDENTIALITY

The information provided by you in the questionnaires and focus group discussions will be used for research purposes. It will not be used in a manner - which would allow identification of your individual responses.

All the information that we collect from the questionnaires and focus group discussion will be kept in a locked password protected computer and will not be available to others. The records from your participation may be reviewed by people responsible for making sure that research is done properly, including members of the ethics committee at the University of the Free State (All of these people are required to keep your identity confidential).

We are asking you to give us permission to tape-record the focus group discussion so that we can accurately record what is said. We will not record your name anywhere and no one will be able to connect you to the answers you give. Your answers will be linked to a name that is not real (another name) and we will refer to you and what you say in this way in the data, any publication, report or other research output.

WITHDRAWAL CLAUSE

Participation in this research study is your choice. You may refuse to participate at any time, even after signing this form. If you choose not to take part, you will not be affected in any way whatsoever.

RISKS/DISCOMFORTS

We will make every effort to keep what you say confidential. However, while I ask that other members of the discussion group please keep what is shared here as confidential, I cannot guarantee that they will do so. Thus, you need to be aware of what you disclose to the group. Therefore, as a participant, you are advised not to disclose sensitive personal information in the group discussions.

POTENTIAL BENEFITS OF THE STUDY

There are no immediate benefits to you from participating in this study. However, this study will be helpful to us to promote policy making around smallholder farming in South Africa.

CONTACT INFORMATION

If you have any questions about the research study, please contact Mbongeni Maziya on 0738649019 or Professor B. Nkonki-Mandleni (Supervisor) on 031 819 9413.

CONSENT FOR PARTICIPATION

I have read the form. I have had an opportunity to ask questions and I am satisfied with the answers I received. I hereby agree to participate in research on *Smallholder farmers' perception and adaptation to climate change: a case of uMkhanyakude district in KwaZulu-Natal province of South Africa.* I understand that this is a research project whose purpose is not necessarily to benefit me personally in the immediate or short term. I understand that my participation will remain confidential.

……………………………..

Signature of participant **Date**:…………………..

APPENDIX E: ETHICAL CLEARANCE

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

21-Jul-2020

Dear Mr Mbongeni Maziya

Application Approved

Research Project Title:
Smallholder farmers' perception and adaptation to climate change: a case of uMkhanyakude district in KwaZulu-Natal province of South Africa

Ethical Clearance number:
UFS-HSD2020/0632/2107

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

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