PERCEIVED-EFFECTS OF CLIMATE VARIABILITY AND ADAPTIVE STRATEGIES UTILIZATION AMONG SMALLHOLDER SUGARCANE FARMERS IN NKOMAZI, SOUTH AFRICA

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A research dissertation submitted for the Master of Agriculture degree in Agricultural Extension and Rural Resource Management

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DECLARATION:

I hereby declare that the above-mentioned dissertation/ thesis is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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DATE: 02 March 2025

SUPERVISOR SIGNATURE: ______________________

DATE: 03/04\2025

DECLARATION

I, Xolani Pennial Presence Nkosi, declare that this dissertation, entitled "**PERCEIVED EFFECTS OF CLIMATE VARIABILITY AND ADAPTIVE STRATEGIES UTILIZATION AMONG SMALLHOLDER SUGARCANE FARMERS IN NKOMAZI, SOUTH AFRICA**", submitted to the University of Mpumalanga for the degree of Master of Agriculture in Agricultural Extension and rural Resource Management in Agricultural Science. The work contained herein is my original work with exemption to the citations and this work has not been submitted to any other University in partial or entirely for the award of any degree.

Name: Xolani Pennial Presence Nkosi

Signature: Date: ……………………………………………

DECLARATION ON PUBLICATIONS RELATED TO THE RESEARCH

1. Publication 1- Undergoing review

Perceived effects of climate variability and adaptive strategies among smallholder sugarcane Farmers in Nkomazi, South Africa.

Authors: Nkosi, X.P.P., Matiwane, B. M. and Olorunfemi, O.D.

DEDICATION

This dissertation is dedicated to the All-Powerful GOD (YAHUAH, YAHUSHA, THE HOLY SPIRIT). The writing process has been an enriching and challenging experience for me. I am grateful for your love, strength, guidance, and grace. Also, my sincere gratitude extends out to my parents, Mr. Grey Griffith, aka (Mfana) Nkosi, and my late mother, Ms Duduzile Rosemary Nyalunga, who always believed in me regardless of any circumstance. The writing process would not have been possible without the support of my wife, Mrs TN Nkosi, my children, and friends. Faith in God, coupled with hard work, perseverance, and fortitude, makes the impossible possible.

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"ABOVE ALL TO GOD BE THE GLORY FOREVER".

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LIST OF ACRONYMS

IPCC	Intergovernmental Panel on Climate Change
DARDLEA	Department of Agriculture, Rural Development, Land and Environmental Affairs
IPCC	Intergovernmental Panel on Climate Change
SSFs	Smallholder Sugarcane Farmers
UNFFCCC	The United Nations Framework Convention on Climate Change
PACEST	Presidential Advisory Council on Education, Science & Technology
DAFF	Department of Agriculture, Forestry, and Fisheries
IKS	Indigenous Knowledge System
IF	Indigenous forecasts
SF	Scientists forecasts
CSA	Climate Smart Agricultural
IKSCF	Indigenous knowledge seasonal climate forecast products
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change (IPCC)
SPSS	Statistical Package for Social Science
SD	Standard Deviation
TPB	Theory of Planned Behaviour

ABSTRACT

Smallholder farmers in developing countries face numerous challenges due to climate variability. In South Africa, smallholder sugarcane farmers are particularly vulnerable to these fluctuations because they rely on rain-fed agriculture. Moreover, the adaptability of these farmers is hindered by various factors. The aim of the study was to assess the perceived effects of climate variability on smallholder sugarcane farmer and their adaptive strategies. A two-stage sampling procedure was employed to elicit data from a sample of 205 smallholder sugarcane farmers draw from the total study population of 421. A Mixed research method was used to collect data. Descriptive statistics and an inferential model (multiple linear regression) were employed to analyse data to archive research objectives and hypotheses.

The study findings reveal that 98.1% of smallholder sugarcane farmers perceive climate variability as having a detrimental effect on their sugarcane production and livelihood. Increased temperatures were perceived to be leading to drought, which resulted in low sugarcane production and high crop failures (97%). Consequently, this led to soil degradation and erosion (98.1%). Additionally, study participants demonstrated a moderate level of knowledge regarding strategies for adapting to climate variability. However, the study also revealed that despite the availability of numerous adaptive strategies, most of these strategies were not utilized by these farmers due to certain severe constraints faced. Furthermore, multiple linear regression results revealed that age, family size, secondary occupation and years of farming experience were significant determinants of smallholder farmers utilization of adaptive strategies. The study recommends that extension agencies provide sugarcane farmers with climate variability information and training on various sustainable adaptive strategies. Continuous updates in their knowledge and skills will enhance their adoption of adaptation and mitigation strategies for improved livelihoods.

Keywords: Climate variability; Perception; Smallholder sugarcane Farmers; Knowledge; Adaptive strategies.

CHAPTER ONE
INTRODUCTION

1. Chapter introduction

This chapter provides background information of the study, a statement of the problem, research questions, the study's aim, the study hypothesis, justification, limitations, and scope. It also outlines the dissertation structure, defines key terms, and provides a summary.

1.1 Background of study

Sugarcane's importance can be attributed to its strategic position and bulk use in daily life as well as its industrial uses that contribute to dietary and economic nutrition (Owino et al., 2019). Since sugarcane is a tropical and subtropical crop, it plays a vital role in the global economy (Zulu et al., 2019). Sugarcane grows best in humid, high-altitude areas with high rainfall rates, such as India and southern Africa. The world's largest sugarcane producer is Brazil, whose production is 768, 678, 382 metric tonnes, while India's production is 348, 448,000 metric tonnes (Ambetsa, 2020). Currently, Brazil and India are tied for first place as sugar producers, and Pakistan is fifth (Annual Report of the Pakistan Sugar Mills Association Islamabad, 2020-21). Sugarcane accounts for 85% of all sugar produced in the world (Ambetsa et al., 2020). According to the SASA report (2018), South Africa is among the top 15 countries that produce cost-competitive, high-quality sugar.

Travella and Oliveira (2017) indicate that Sub-Saharan African countries produce approximately 80% of the world's sugar production. In Africa, South Africa, Sudan, Swaziland, Zambia, Mauritius, and Kenya are responsible for over half of the total sugarcane production (Travella & Oliveira, 2017). In South Africa, DAFF (2018) reports that KwaZulu-Natal and Mpumalanga are the most prolific sugarcane-producing provinces. Moreover, registered cane growers supply cane to sugar mills for processing. A total of 270,000 jobs are estimated to be created through indirect employment. In South Africa, approximately 2% of the population rely on the sugar industry for a living (South African Sugarcane Association, 2024). The South African Sugar Association reports the industry ranks 15th among 120 premium sugarcane producers worldwide based on cost competitiveness. The sugar industry sells 75% of its products domestically and internationally (DAFF, 2019). According to the South African Sugar Association, 70% of this sugar is exported to the Southern African Customs Union (SACU). The remaining products are exported to markets in Africa, Asia, and the United States. In KwaZulu-Natal and Mpumalanga, where sugarcane is grown, sugarcane contributes nearly 50% of the gross agricultural income across the two provinces (SASA, 2022). As a result of its emphasis on socio-economic development, the sugar industry creates jobs, earns foreign exchange, organizes resources, provides income, and develops transportation and communication networks, all of which contribute to South African GDP (Zulu et al., 2019). Furthermore, Wang et al. (2020) note that sugarcane contributes to over 80% of the world's sugar revenue. As reported by SASA (2019), the company has up to 85,000 direct employees (producers and processors) and up to 350,000 indirect employees (suppliers).

Despite positive industry indicators, South Africa's sugarcane production industry experiences chronic yield declines (Dubb, 2013). A similar trend is observed in other countries besides South Africa, where sugar is produced (Jones et al., 2012). Other studies have reported similar findings in Australia (Garside et al., 2001), and Mauritius (Seeruttun et al., 2014). Jones et al. (2012) study did not attribute the decline in yield to anything specific but excluded climate variability and harvest age as contributors. Garside et al. (2001) and Seeruttun et al. (2014) attributed the yield decline to prolonged sugarcane monoculture. Several factors have been attributed to the negative output trend, including high input costs, limited availability and usage of recommended technologies, droughts, instability in the global economy, and inadequate infrastructure, according to Girei & Giroh (2012). From the early 2000s to 2011, these factors resulted in a steep decline in smallholder sugarcane growers from 50,000 to less than 13,044 (Dubb, 2013). In the 2014/15 and 2015/16 production periods, the industry lost 12.7% of its yield because of drought (SASA, 2019). It has been evident that ongoing production issues threaten farmers' productivity and processors' profitability.

Previous trends show sugarcane production has decreased tremendously across the globe. While this may be true, it is estimated that the world's sugar production will decline by 3% from 1745 million tons in 2019-2020 to 1745 million tons in 2021, with 26.5 million ha of sugarcane expected to be planted (Annual Report of the Pakistan Sugar Mills Association, 2020-21). Nonetheless, no literature has been found that investigates smallholder sugarcane farmers' perceptions, knowledge levels, and use of recommended adaptive strategies concerning climate variability. Also, mitigation measures for ensuring the sustainability and profitability of the sugarcane industry have not been suggested. However, several factors have been recommended to mitigate climate variability, including the use of climate-adapted varieties, improved management practices, irrigation and drainage systems, and the use of fertilizers and pesticides (Linnenluecke et al., 2018; Oliveira et al., 2018). As of now, upon review of available literature, it is evident that there is little information on the extent to which smallholder sugarcane farmers in South Africa especially in Mpumalanga province, are aware of and understand the effects of climate variability on sugarcane yields. Thus, a research study is required to address this gap by providing the government, extension agencies, and other interested parties with empirical data and insights into climate variability effects. Climate variability adaptation and mitigation plans reduce farmers' vulnerability to climate fluctuations. Thus, the study assesses the perceived effects of climate variability and adaptive strategies utilized among smallholder sugarcane farmers in the Nkomazi area of South Africa.

1.2 Statement of the problem

South Africa has experienced extreme climate variations and global warming for three decades (IPCC, 2017). Numerous studies have demonstrated that this phenomenon moves almost twice as fast as global warming trends, especially in sugarcane production. Climate variability has a negative impact on smallholder sugarcane farmers' productivity, threatening their livelihoods (Elum et al, 2017). Several studies have examined the effects of climate variability and change (; Linnenluecke et al., 2018, 2020; Pipitpukdee et al., 2020; Christina et al., 2021; Flack-Prain et al., 2021; Guo et al., 2021). A study conducted by De Medeiros Silva et al. (2019) observed that Brazil's rising temperatures harmed sugarcane production, while precipitation increased it. Based on SantillánFernández et al. (2016), sugarcane yields decreased because of lower rainfall. Ranomahera et al. (2020) found that rainfall rates may influence sugarcane productivity in East Java, Indonesia, significantly. These factors may also have contributed to the decline in sugarcane production from 50,000 tons to less than 13,044 tons between 2000 and 2011 (Dubb, 2013). Similarly, drought reduced smallholder sugarcane production by 12.7% in 2014/15 and 2015/16 (SASA, 2019). Droughts and floods are among the most significant challenges facing smallholder sugarcane farmers. Ncoyini, Savage, and Strydom (2022) also identify extreme weather variability as one of the greatest threats. It is generally the case that smallholder sugarcane producers in South Africa are predominantly rural, resource-poor communities that lack access to appropriate information and resources regarding adapting to climate variations to improve sugarcane yields.

Smallholder sugarcane farmers suffer adverse effects due to their dependence on rain-fed agriculture. There is a lack of climate knowledge and skills, high levels of illiteracy, low adoption of technology, and a lack of climate adaptability, which contribute to the inability of extreme climatic events to be predicted (Maponya et al., 2013; Ouedraogo et al., 2018; Phuong et al., 2018). The effect of climate variability on agricultural productivity has been demonstrated in several studies (Mesquita and Bursztyn, 2016; Ortiz-Bobea et al., 2021; Zhu et al., 2022). It has also been found that smallholder sugarcane farmers are extremely vulnerable to climate variations (Harvey, et al., 2018; Jamshidi, et al., 2019). In response, scientists and research organizations have developed a variety of environmental and technological innovations and strategies to deal with the threat posed by climate variability to sugarcane farmers to sugarcane farmers. However, despite the availability of some of these strategies, chronic yield losses continue to plague the sugarcane industry in South Africa (Dubb, 2013). According to Metiso and Tsvakirai (2019), smallholder sugarcane farmers especially in the Mpumalanga province continue to experience production decline. Furthermore, RCL Foods (2018) reported a drastic decline in sugarcane production among smallholder farmers in Nkomazi local municipality. Some scientists believe that this may be due to farmers' inability to accept and use existing adaptive and mitigation strategies that can mitigate the adverse effects of climate variability.

According to Olorunfemi and Oladele (2018) a person's attitude, which is determined by their knowledge, together with the perception of the innovation, leads to the adoption of the innovation. Understanding smallholder sugarcane farmers' perceptions and knowledge levels is essential to understanding climate variability. It cannot be overstated how imperative it is to assess smallholders' perceptions and strategies for reducing climate variability in the study area. This is to enhance sugarcane production there. Few studies have been conducted on smallholder sugarcane farmers' perspectives on climate variability. This study fills this gap by examining smallholder sugarcane farmers' perceptions regarding climate variability. As well as assisting farmers in implementing sustainable practices, climate information can also be provided to them. Consequently, the agricultural sector will become more resilient to climate variability as a result.

1.3 Research questions.

1. What are the perceived effects of climate variability on sugarcane production in the area?
2. What is the knowledge level of smallholder sugarcane farmers regarding climate variability adaptive strategies?
3. What are the adaptive strategies utilized by smallholder sugarcane farmers to cope with climate variations in the area?

1.4 Aim of the study

This study is aimed at assessing the perceived effects of climate variability and adaptive strategies utilized amongst smallholder sugarcane farmers in the Nkomazi area of South Africa.

1.4.1 The objectives of the study were to:

1. Determine the perceived effects of climate variability influencing sugarcane production in the area.
2. Examine smallholder sugarcane farmers’ knowledge on climate variability adaptive strategies.
3. Ascertain adaptation strategies utilized by smallholder sugarcane farmers.

1.5 Study Hypotheses

Ho1: There is no significant difference in the smallholder sugarcane farmers production output across two (2) growing seasons.

Ho2: Smallholder sugarcane farmers socio-economic characteristics does not influence their utilization of climate variability adaptation strategies.

1.6 Justification for the study

There is no doubt that climate variability is one of humanity's greatest challenges. This phenomenon has a significant impact on the poor's livelihoods. Sub-Saharan Africa is currently experiencing climate variability due to its lack of capacity to adapt and respond to it, as well as its reliance on agricultural, forestry, and fishing sectors susceptible to climate change (World Bank, 2008; Bryan et al. 2013). Approximately 80% of agricultural production in sub-Saharan Africa is produced by smallholder farmers. A study by Bryceson (2019) indicates that smallholder agriculture significantly contributes to local economic development and poverty alleviation. Lekhuleni (2020) reports smallholder farmers contribute to local development, food security, and livelihoods. There are approximately 70% of smallholder farmers in SSA. Most are female, and their vulnerability is greater since they lack access to information and farm inputs, use 'old-fashioned' technology, have low incomes, are subject to seasonal labour fluctuations, or do not receive extension services as their male counterparts do (Harris and Consulting, 2014). Although this is the case, climate variability places severe challenges on low-input farming systems, which results in increased poverty in rural areas. Moreover, in the National Planning Commission (2012) report, smallholder farmers in rural areas face different challenges than those in urban areas. Smallholder farmers in remote settings lack financial assistance to cope with climate variability and change. They move away from labour-intensive and low-yielding traditional farming practices. Because of these factors, smallholder farmers in Sub-Saharan Africa are adversely affected since their livelihoods depend on rain-fed agriculture (Anderson et al. 2018, Alemayehu et al. 2017). Additionally, this sector contributes to the reduction of hunger and poverty within household structures (IFAD, 2008).

However, these problems enable us to explore the knowledge gap regarding how climate influences smallholder sugarcane production. In addition, they enable us to explore how farmers cope with climate variability caused by weather pattern changes. Moreover, Africa is particularly vulnerable to climate change, as well as weather variability and instability (Hubertus, 2020). Climate variations adversely affect agricultural and household farming yields. South Africa and other African countries face climate instability and transition risks. Consequently, this study will help smallholder sugarcane farmers understand climate variability and develop strategies to minimize its effects. Additionally, policymakers may use the study recommendations to advise farmers on how to reduce climate variability's impacts. This will ultimately help farmers increase their yields and ensure food security. The study will also provide a better understanding of the effects of climate change on small-scale farmers in South Africa and other African countries.

1.7 The Study’s Limitations and Scope

The objective of this study was to assess smallholder sugarcane farmers' perceptions of climate variability and adaptation strategies in the Nkomazi municipality areas of South Africa. Participants were smallholder sugarcane farmers in the municipality of Nkomazi who supplied sugarcane to RCL Foods (Komati Mill). A questionnaire was administered by an enumerator to elicit data, assuming the answers provided by the smallholder farmers were accurate. Further, some of the participants were harvesting sugarcane at the time of the initial data collection phase, which made it impossible to conduct interviews simultaneously. Consequently, data collection was delayed. However, to resolve this issue, DARDLEA officials requested onsite meetings with study participants. This provided researchers with an opportunity to interview participants after each briefing. The researchers were able to gain valuable insights by understanding the participants' experiences through this process. Furthermore, the onsite meetings provided researchers with the opportunity to establish relationships with the participants, which is crucial to the successful collection of data.

1.8 Dissertation structure

Chapter One

Chapter I- Introduction: This introductory chapter presented the rationale of conducting the research. Focus was on, among other issues, background of the study, statement of the problems, aim of the study, research objectives, research questions, significance of study, and limitation of study.

Chapter Two

Chapter II- A review of literature: this chapter reflects on concepts and an understanding of climate variability as short-term fluctuations around the average weather variables and in terms of erratic and uncontrolled heat waves, rising temperatures, changes in rainfall patterns are likely to pose a threat to agricultural production. It also highlights the causes and the effects of climate variability. Smallholder perception, and knowledge regarding the effects of climate variability, as well as available adaptive strategies to cope with these effects, as well as the agricultural extension support and services. These areas formed the basis upon which empirical chapters are originated. It carries the main theoretical concepts out of which the author found the basis to articulate some arguments.

Chapter Three

Chapter III- Research Methodology: The chapter presented research methodology that included research philosophy, research design, sampling, ethical considerations, data analysis and presentation procedures. Furthermore, it offers a detailed explanation of the research instrument, its validity and reliability, and the model that was employed during the data analysis phase.

Chapter four

Findings and discussion of descriptive analysis

Chapter VI- This chapter presented the findings and discussion of the data analysis results. It was broken down into four (4) sections, each focusing on a specific study objective. The various sections of the study report on the results and discussion of the socio-economic characteristic of the smallholder sugarcane farmers, the perceived effects of climate variability on sugarcane production, the knowledge of smallholder sugarcane farmers regarding climate variability adaptive strategies, and the adaptation strategies utilized in the study areas. The results are presented mainly in the form of figures, tables and graphs. The results were discussed and where viable compared and linked to literature.

Chapter Five

Findings and discussion on inferential analysis

Chapter VII- The chapter provides the findings and discussion on the inferential analysis of the study hypotheses used to relate key variables in the study together and draw appropriate inferences. The following hypotheses stated in the null form were statistically tested in the study. The first hypothesis was to statistically test whether there is no significant difference in the smallholder sugarcane farmer's production output in 2020 and 2022 growing seasons. This was achieved using paired sample t-Test analysis. Also, the second research hypothesis was to statistically test whether the smallholder sugarcane farmers socio-economic characteristics does not influence their utilization of climate variability adaptation strategies. This was also achieved using multiple linear regression analysis.

Chapter Six

Chapter VIII- presents the study Summary, conclusion, and recommendations: This chapter presents a summary of the scope of this thesis. It wraps up the major findings from the study.

1.9 Definition of terms

Climate change: An increase in temperature and precipitation that occurs over a long period (probably over 10 years) is called climate change. This refers to the increase in the average temperature of the surface of the earth. Global climate transformation is characterized by changes in the environment of the planet. A climate change occurs when the average climate or climate variability change over time. Globally, this phenomenon has already been established.

Adaptation Strategies: According to IPCC (2014), climate change adaptation is "adjusting to actual or expected climate impacts". "Adaptation" refers to minimizing or avoiding harm or exploiting benefits. In general, the concept refers to adjusting livelihood practices to cope with new climate conditions. As well as adjusting to potential risks and damages, a system is able to cope with the consequences (Africa Partnership Forum 2007). Climate variability is addressed by a variety of techniques, approaches, and actions used by smallholder sugarcane farmers.

Smallholder sugarcane farmers: Farming operations that use family labour and are focused on subsistence production in rural areas. The majority of their farms are small and located in risky or marginal environments. Among the risks are droughts, floods, disease outbreaks in crops and animals, and market fluctuations. Small-scale farmers are farmers who possess a small plot of land (1 hectare to 2 hectares); they have limited resources and grow subsistence crops and a few cash crops (DAFF, 2016). Smallholders are farmers who own land plots typically measuring less than two hectares and rely primarily on family labour for their livelihoods (FAO, 2019).

Climate variability: Refers to the short-term deviations on seasonal or Mult- seasonal timing in climatic variables such as temperature and precipitation. Deressa *et al., (*2011); Nhemachena *et al.,* (2016) defines, climate variability in terms of erratic and uncontrolled heat waves, rising temperatures, changes in rainfall patterns, droughts and flooding are likely to pose a threat to crops and livestock production. In addition, Okumu, (2013) state, that climate is categorised by different components of climate variables, such as temperature, rainfall, Atmospheric humidity, Solar radiation, Wind velocity and Atmospheric gases etc.

Global warming: Global warming refers to the average increase of the Earth's temperature due to the greenhouse effect caused by carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydro fluorocarbon (HFCs), perfluorocarbon (PFCs) and sulfur hexafluoride (SF6). Global warming, meaning a continuous increase of the Earth's temperature due to the greenhouse effect, started from the time of the Industrial Revolution which was accompanied by a rapid increase of fossil fuel consumption. (Presidential Advisory Council on Education, Science & Technology: PACEST, 2007).

Climate: This refers to a long-term change in the atmospheric condition of a specific region or area.

Perception: The process by which information is received and transformed to create a psychological awareness. People perceive the same information differently based on their cultural differences and previous experiences. Perception in the context of this study is viewed one's perception is shaped by experiential and or indigenous knowledge of the climate as well as given the observed effects of climate change and variability. Process of understanding human behaviour, because every person perceives the world and approaches life problems differently (IPCC, 2018). A person's frame of reference emerging from previous experiences, beliefs, likes, dislikes opinions, feelings, and other psychological factors of unknown origin (Barrios & Costeil, 2004; Ayal and Filho, 2017).

1.10 Summary of the chapter.

The purpose of this chapter is to introduce the study through outlining its background and statement of the problem. It includes research questions, aim of the study, justification for the study, limitations and scope of the study, structure of the dissertation, definition of key terms, and summary of the chapter.

CHAPTER TWO
LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Chapter Introduction

Climate variability is a global phenomenon that is experienced throughout the world. This chapter reflects a comprehensive understanding of climate variability, as short-term fluctuations around average weather variables as well as heat waves that are erratic and uncontrollable, rising temperatures, and changes in rainfall patterns that threaten agricultural production. It also, provides an overview of the causes and consequences of climate variability, smallholder farmers perceptions, and knowledge regarding the effects of climate variability, available climate adaptive strategies, and farmers access to agricultural extension services.

2.2 Concepts of Climate variability

The term climate variability is used to describe a systematic change in the climate of the earth (such as temperature changes, precipitation changes, and wind changes) because of human activity (Antwi-Agyei & Nyantakyi-Frimpong, 2021). Global warming is primarily responsible for global climate variability and change due to greenhouse gas emissions (mostly carbon dioxide, methane, nitrogen oxide, and fluorine gases) generated by coal, oil, and gas burning, deforestation, and livestock production (European Commission, 2021). It has been observed that the global average temperature is 1.1 degrees Celsius above pre-industrial levels (earlier 1850) in 2019 compared to the previous decade (2011-2010) making it the hottest decade on record. Zwane, (2019) also reports an increase in temperature of 0,8 and 0,68 degrees Celsius, respectively, compared to 2018. Several regions are experiencing an increase in precipitation, resulting in heavy downpours and flooding. It may vary depending on the region. Rainfall may not be sufficient in some areas, causing droughts.

Global temperatures have increased by 1.0°C, or 0.21°C per decade, since 1960 (World Bank, 2021). There was a two-degree Celsius increase in temperature during the Industrial revolution. It has been demonstrated that rising temperatures have negatively impacted human health and well-being, including the possibility of dangerous and potentially catastrophic changes in the environment (European Commission, 2021). Barnes et al., (2021) assert that rising temperatures are likely to cause floods, droughts, storms, wildfires, and tropical diseases to spread. This leads to an imbalance in Earth's weather. Global economic stability and mankind's future are at risk due to climate change. Food supplies worldwide are also at risk due to climate change.

Climate variability refers to changes in temperatures or precipitation over a short time, such as a decade or 30 years (PACEST, 2007). These changes can be seen in the spreading of temperatures and clouds, as well as the distribution of rainfall (PACEST, 2007). Moreover, Aryal et al., (2019) testify that weather patterns affect water supplies, forestry, agriculture, and livelihoods. Gioto et al. (2016) report that rainfall in Tharaka-Nithi County decreased between 1960 and 2009. Agricultural sectors are the most vulnerable because they are dependent on natural systems. Moreover, a variety of extreme weather events affect agriculture, including heat waves, droughts, salinization, and disruptions to agricultural supply chains (Cohn et al., 2017). The effects of climate variability can be mitigated through the use of technologies, such as heat tolerance, salinity tolerance, drought tolerance, and early maturing crops, as well as irrigation, water conservation, and storage technologies (Cohn et al., 2017).

Agriculture in developing countries suffers from climate variability. Weather patterns will change, resulting in higher temperatures, droughts, and floods. Crop yield, land efficiency, and soil quality are negatively affected by flooding and droughts, which submerge farms, wilt crops, and cover soil. These soils ultimately determine food security. Further, climate variability is an alteration of the atmosphere that can be detected statistically by changes in mean and variations in its characteristics over time, which can last decades or more (Elum et al., 2017). Moreover, these changes will differ in magnitude, direction, and variability not only globally, but also locally and regionally. We can expect these human-induced climate changes to be more severe than what we are currently experiencing in South Africa if we consider both natural climate variability and other stresses faced by the agriculture sector (Sivakumar, 2021).

In South Africa, agricultural production has been adversely affected by climate variability, making it necessary to adapt. Since agricultural output is heavily influenced by the temperature and precipitation conditions of the region in which it is carried out, climate variability directly impacts its productivity. Furthermore, Ornes (2018) points out that climate variability has led to an increase in global temperatures above average, which may be accompanied by supplementary environmental changes, including an increase in sea levels, which may result in flooding, storms, and heat waves. Worldwide, climate variability poses a significant challenge to agricultural producers. WIRED, 2018) reports that climate variability affects weather patterns and adversely impacts food production. Those living in poverty are most likely to suffer from climate variability. Developing countries are the most vulnerable to climate change due to their reliance on natural resources, assets, and materials, as well as their need to adapt to unpredictable climate conditions. Dastgerdi et al. (2019) demonstrate that our daily activities contribute to climate change.

2.3 Climate variability affects agricultural production.

Climate variability and change have emerged as humanity's most pressing concerns in the past four decades. It is therefore necessary to understand society's perception of climate change in order to minimize and adapt to its effects. This topic was addressed in the IPCC's 2017 report. The effects of climate variability cannot only be seen locally and regionally, but also on a global scale. As reported by Bryan et al., (2009), agriculture provides 40% of the world's food supply and is one of the main sources of income for rural communities. The agricultural sector provides a significant portion of the livelihood for rural communities (Shah, 2017). The agricultural sector is highly vulnerable to climate change, with the result being increased droughts, floods, reduced yields, crop failures, and livestock deaths (Naab et al., 2019). According to Ali et al. (2017), climate variability also influences crop yields, food security, and livelihood vulnerability. Climate variability poses a significant risk to agricultural businesses since their productivity directly depends on the weather conditions in which they operate (Tol, 2018). In addition, Dube et al. (2016) found that smallholder farmers are at risk of climate variability impacts due to their limited ability to adapt and reach sustainable livelihoods.

The agricultural sector is responsible for 2.6% of South Africa's GDP and employs 5.1% of its workers (DAFF, 2018). The South African agricultural economy is divided into two segments: a well-developed commercial sector and a much less developed smallholder sector (DAFF, 2018). Naab et al., 2019 emphasize the importance of climate change policy and implementation tactics for solving these pressing problems in the long run. According to Vogel et al., 2019, climate variability threatens our ecosystem, society, and several nations. Most Africans depend on agricultural activities for their livelihoods. Climate variability is particularly prevalent in South Africa. Agricultural productivity is anticipated to decrease in vulnerable areas, primarily due to reduced crop yields, as empirical literature evidence shows (Malhi et al., 2021). Climate variability poses a particular threat to South Africa, according to Maponya and Mpandeli, (2017). Therefore, water shortages and droughts are most harmful to smallholders and subsistence farmers (Ubisi et al., 2017). In addition to floods, droughts, fires, hail, extreme temperatures, pests, and diseases, climate change has adverse effects on the environment. According to Richardson et al. 2022, climate variability and extremes are key drivers behind rising global hunger, especially in food-insecure regions. The IPCC et al. (2017) report shows that climate variability impacts crop yields more negatively rather than positively. Therefore, most countries that rely on this sector could be impacted by climate uncertainty.

2.4 Effect of climate variability on smallholder farmers.

Agriculture is one of the economic sectors most sensitive to the effects of climate change since its productivity depends directly on the temperature and precipitation conditions of the geographical area where it is carried out (Tol, 2018). in Southern Africa, agriculture is a spearhead for economic growth and rural development, were 70% of rural dwellers live off the agricultural sector (Mbatha & Masuku, 2018). The agricultural sector on the continent is dominated by smallholder farmers, who compose nearly 80% of the total farms (Hlophe-Ginindza and Mpandeli, 2020). Smallholder farmers play a crucial role in food security, according to the literature (Hlophe-Ginindza and Mpandeli, 2020). The smallholder agriculture sector has been identified as one of the most important economic assets for many rural South Africans. Donatti et al. (2018) found that over 80% of the food consumed in underdeveloped and developing countries comes from smallholder farmers. Generally, impoverished people in rural regions look to smallholder agriculture to escape poverty and generate income (Oluwatayo, 2019). Furthermore, It has been demonstrated in numerous studies that smallholder agricultural practices are essential to the development of rural economies and the well-being of the poor (Bryceson, 2019). Despite the positive attribute of smallholder farmers are having a hard time maintaining agricultural practices because of the many challenges they are facing, climate variability been in the centre of their constraints. In general, studies show that climate change is more likely to impact crop yields negatively rather than positively (IPCC et al., 2014). Thus, climate uncertainty has compromised the economic performance of countries which depend on this sector In Sub-Saharan Africa, smallholder farmers rely on rain-fed agriculture for their livelihoods (Alemayehu and Bewket, 2018). As a result, smallholder farmers suffer from a negative impact mainly because they depend on rain-fed agriculture and natural resources. Because of a lack of climate information and skills, high levels of illiteracy, low adoption of technology, limited financial capacity, and poor adaptive capacity, it is difficult to determine the likelihood that extreme climatic events will occur (Ouedraogo et al., 2018; Phuong et al., 2018).

There is a great deal of risk associated with climate variability. Allen et al. (2018) have found that global surface temperatures have increased since the 19th century. This means that the continuous anthropogenic increase in greenhouse gas concentrations is leading to an increase in surface air temperatures, resulting in more frequent heat waves and heat extremes (IPCC, 2018). Moreover, Tesfahunegn et al. (2016) indicated that the rise in temperatures and the decline in precipitation have significantly reduced agricultural productivity and resulted in a greater incidence of pests and diseases among smallholder farmers. Several studies have documented the vulnerability of smallholder farmers to the effects of climate variability (Harvey, et al., 2018). As a result of climate variability, instabilities, and transitions, developing countries, particularly those in Sub-Saharan Africa, are disproportionately affected (Jamshidi et al., 2019). According to Engelbrecht et al., (2015), Southern Africa's surface temperatures are increasing twice as fast as global warming, which is causing changes in rainfall patterns and extreme weather events such as wildfires (Abiodun et al., 2017; Ouedraogo et al., 2018).

The Intergovernmental Panel on Climate Change (IPCC) assessment report of (2017), states that, climate variability has significantly affected global agriculture, as indicated in many countries, average temperatures have increased, heat waves have become more frequent, water resources have become increasingly stressed, desertification has occurred, and heavy precipitation has occurred (IPCC,2018). Increasing atmospheric greenhouse gas (GHG) emissions have resulted in increased variability and seasonal uncertainty in the past few decades (Ray et al., 2019; Wiebe et al., 2019).

2.5 Smallholder farmers perception on climate variability

A significant decrease in agricultural production has been attributed to rising global atmospheric greenhouse gas (GHG) emissions over the past few decades (Ray et al., 2019; Wiebe et al., 2019). Extreme weather patterns and climate characteristics, such as higher temperatures, erratic rainfall, frequent floods, and prolonged droughts, have been shown to have greater impacts in sub-Saharan Africa (SSA), where over 95 percent of arable land is rainfed and approximately 80% of the population relies on subsistence agriculture (Serdeczny et al., 2017). In South Africa, farmers have observed changes in rainfall patterns, increased temperatures, and severe weather events that could result in death (Talanow et al, 2021). Based on the results of Talanow et al (2017), Masuku and Mbatha (2018) concluded that summer rainfall levels have decreased over time. On the other hand, Ajala (2017) demonstrated with the aid of a diagram that the Lowveld region has experienced a temperature increase over the last thirty years. It is evident from these findings that the climate in South Africa varies according to the location.

Farmers in most SSA regions have reported and observed declining precipitation amounts as well as rising air temperatures as the most prominent indicators of climate variability (Ochieng et al., 2017). As a result, finding out how farmers perceive climate variability may help develop climate policy, mitigation, adaptation, and sustainable agriculture strategies. Further, there is evidence that farmers' poor perceptions or awareness of climate variability or climate changes may be the result of a variety of factors such as age, indifference, a lack of information, financial constraints, and off-farm practices (Deressa et al., 2011). Ochenje et al (2016) note that the foundation of an effective intervention begins with understanding the needs and perceptions of the targeted group to make informed and relevant decisions, and this is crucial for directing efforts in the right direction. Farmers' perceptions are influenced by their observations, experiences, and the weather variations and risks they face (Tanalow et al, 2021). Kumagai (2017) asserts that perception is the ability to interpret what is perceived, to understand and recognize things quickly, using their senses of sight and hearing. Also, Kebede and Nakkiran, (2020) emphasize that, perception is the individual's unique way of seeing a phenomenon that influences the processing of stimuli and incorporates memories and experiences into the process of understanding. Hussain et al., (2019) defined perception as the ability of a person to recognize an object or event using their senses. De Lange (2018) further explained perception as a method of diagnosing, distinguishing, recognizing, and judging items, attributes, or social relationships through sense information. Individuals use their sense organs to learn about their physical and social environments. Furthermore, Sun (2020) claimed that social, psychological, and cultural aspects have a direct impact on how people perceive innovations.

According to Fakkhong et al., (2016), farmers' perceptions can greatly influence their farm management decisions as well as their economic situation. Though, farmers' perceptions of climate variability are influenced by factors such as farm household characteristics, historical climate experiences, and knowledge. In addition to socio-cultural and geographical factors, climate variability affects agricultural productivity. There are various studies suggesting that farmers perceive climate variability and change have developed coping strategies to mitigate its negative effects (Deressa et al., (2009); Mertz and Reenberg, (2009). Since perception needs to be followed by action. Smallholder farmers who understand that the climate is changing respond by adapting to it. According to Weber (2010), farmers' perceptions determine the way they respond, and they also demonstrate their awareness of the risks of climate change. The study by Woods et al (2015) examined the perceptions of Danish farmers regarding climate variability. In their study, they found that a small group of farmers are sceptical of climate variability and change. Like Milner (2015), 6% of participants disagreed that global temperatures are rising. For agriculture to cope with climate risks, climate-smart agricultural (CSA) technologies need to be adopted (Thornton et al., 2017).

To develop pro-farmer policies and interventions, we must better understand the determinants of farmers' perceptions of climate variability. According to Whitmarsh and Capstick (2018), farmers' perceptions of climate variability are a complex process that includes knowledge, beliefs, attitudes, and practices. An overview of this whole concept as set forth by Hussain et al., (2019) gives us an understanding, that perception is the way in which a person views phenomenon and his/her comprehension of it, including the ideas or beliefs associated with his/her values around that phenomenon. This means that farmers' perceptions of the support services provided will have a direct or indirect effect on the operation and sustainability of agricultural production.

2.6 Smallholder farmers knowledge on climate variability.

Gibson (1984) explains, knowledge is built on perceptual data. The first step in the process is to detect surfaces, events, and objects in the environment. A person with knowledge can extract meaningful information from the environment, thereby guiding actions in an adaptive manner. It involves more than representation and belief, but also perceptual experiences and interactions with the world. In accordance with Berkes (2012), indigenous knowledge refers to a cumulative body of knowledge, practices, and beliefs passed down from generation to generation through cultural transmission, which describes the relationship between locals and their environment and evolves through adaptive processes. Thus, local knowledge offers "observations and interpretations at a much finer spatial scale with considerable temporal depth, highlighting elements that might not have been considered by climate scientists" (IPCC 2018; Jiri et al. 2016).

A lack of adequate climate information reduces farmers' knowledge of climate variability and extremes, therefore affecting their ability to successfully cope with and adapt to them (Popoola et al., 2020). Despite indigenous knowledge's usefulness and success in dealing with seasonal climate variability, it is deemed inadequate due to climate change uncertainty and the potential increase of extreme weather and climate events (Nyadzi et al., 2018). Further, farmers have been using indigenous knowledge for centuries based on their experience of biophysical indicators changing over time (Nyadzi et al., 2018). Moreover, Nyadzi et al. (2017) argue that smallholder farmers are more vulnerable to adverse consequences of climate variability due to a lack of climate information.

IKSs (indigenous knowledge systems) are cumulative bodies of knowledge, practices, and beliefs about the relationships of living creatures (including humans) with each other and with their environment that are handed down from generation to generation by cultural transmission (Berkes 1999). Therefore, IKS has both temporal and spatial dimensions, with the temporal dimension being the passage from one generation to another and the spatial dimension being what happens in each locality. In addition, the term 'indigenous knowledge' refers to accumulated daily experience and knowledge gained through observation. Kom et al. (2022) observed that climate variability and change significantly impact rural farmers, as extreme weather events cause crop failures and reduce livelihood opportunities for farmers. According to Finucane (2009), formal scientific knowledge has been insufficient and limited in addressing local climate change issues in the past few years. Arshad et al. (2017) reported that several rural farmers are concerned about the future impact of climatic variability on agricultural productivity and farm size. For this reason, climate information plays a crucial role in the adaptation process of farmers as well as in neutralizing the effects of climate variability. In rural areas of developing countries, including Africa, where Indigenous knowledge systems are part and parcel of local communities, Indigenous forecasts (IF) remain common. Scientists (SF) are widely disseminated through radio, television, and the Internet (Hoegh-Guldberg et al. 2018).. IKSs (indigenous knowledge systems) are cumulative bodies of knowledge, practices, and beliefs about the relationships of living creatures (including humans) with each other and with their environment that are handed down from generation to generation by cultural transmission. Therefore, IKS has both temporal and spatial dimensions, with the temporal dimension being the passage from one generation to another and the spatial dimension being what happens in each locality.

It has been demonstrated that indigenous information networks have contributed to the establishment and adoption of comprehensive adaptation and mitigation strategies that have reduced the vulnerability of local communities to past fluctuations and variations in climate (Macchi, 2008). There is a high probability that climate patterns will continue to change in the future. Indigenous and traditional cultures can provide valuable information about effective and ineffective adaptations to these changes (Macchi, 2018). Several factors prevent smallholder farmers from adapting to climate change, which makes them unduly vulnerable (Ncoyini et al., 2022). A detailed understanding of the local climate is crucial to sustaining agricultural production under the conditions of climate change. The availability of timely and accurate climate information may assist farmers in making strategic decisions about sustaining and increasing agricultural production. The seasonal variation in climate can be used to determine planting, fertilization, ploughing, pest, and disease management (Ncoyini et al., 2022). Despite the existence of indigenous and customary coping mechanisms to deal with different climatic threats, there is a lack of access to appropriate climate service information in several African countries (Vogel et al., 2019). In addition to providing early warning signs, predicting climate change trends, and developing robust adaptation and mitigation methods, climate services play a significant role in assisting the agricultural sector (Conway, 2011). Rural communities produce indigenous climate forecasts through environmental observation and traditional experience (Singh, Daron, Bazaz, Ziervogel, Spear, Krishnaswamy, et al., 2017).

2.7 Smallholder farmers adaptive strategies to climate variability.

Since more than 80% of sugarcane is planted on rain-fed lands, it is more vulnerable to environmental issues related to climate variability and change (Widyasari et al.,2022). A better understanding of smallholder farmers' responses to climate variability is essential to minimize its adverse effects on farming systems. Thus, this will reduce their vulnerability to climate risks. Climate adaptation practices are adopted largely based on farmers' perceptions of risk and preferences. Studies have shown that farmers' perceptions of climate events influence their adaptation choices (Khan et al., 2020; Singh et al., 2022; Villacis et al., 2021). Furthermore, farmers' risk preferences may also influence their choice of adaptation strategy when faced with climate-related risks to their sugarcane farming system (Hasibuan et al., 2022). The implementation of climate adaptation strategies in developing countries is challenging, particularly for smallholder sugar cane farmers. In the absence of supportive services and limited access to education, income, and management skills, smallholder farmers have limited adaptive capacity (Mulwa et al., 2017; Ncoyini et al., 2022; Tripathi and Mishra, 2017).

Adaptation to climate change is not just influenced by farmer preferences, however. (Ayal et al., 2023; Cinner et al., 2018) suggest that supporting farmers' adaptive capacities can facilitate their adoption of climate risk management methods. A study by Li et al. (2022) found that social interaction and learning processes can contribute to climate adaptation. According to Saptutyningsih et al. (2020); Wuepper et al. (2018) droughts, flooding, and increased temperatures are some of the effects of climate change that are most problematic for agriculture.

Agricultural productivity can be adversely affected by these climatic uncertainties (Dhungana et al., 2020; Xu et al., 2019). Climate variables that affect agriculture production include rainfall, temperature, and agriculture production (Fahad et al., 2018, 2019a). Amanullah et al. (2020) predict that low precipitation will negatively affect crop planting and harvesting in the next two to three decades. Wester et al., 2019 report that many parts of the world have been experiencing unusually high rainfall levels. In a 2019 study, Thakuri et al. predict an increase in average and seasonal maximum temperatures. Therefore, farmers must adapt their agricultural systems to changing weather patterns now and in the future in a multidisciplinary manner. Agribusiness must adopt climate-smart technologies, including harsh weather-resilient crops, to reduce the effects of changing climate patterns on agriculture, and to ensure global food security (Dey, 2022). It is imperative that new ideas, strategies, and technologies take into consideration the environmental, agronomic, social, molecular, and institutional aspects (Harrison et al., 2021; Sloat et al., 2020).

Mavhura et al. (2017) define climate adaptation and mitigation strategies as interventions designed to assist farmers in coping with climate variability. The purpose of climate adaptation strategies is to enable farmers to adapt to the actual or expected effects of climatic factors. It should be noted that adaptation to climate variability is context-specific since its effects vary from one area to another depending on topography and other socioeconomic factors (Sanga et al., 2013). As a result of climate variability and change, some areas have experienced higher temperatures than others, while some are exposed to drought while others have been subjected to flooding. Therefore, each incidence requires a different approach to assist farmers in adjusting to their circumstances (Mavhura et al. 2017).

There are three categories of adoption factors: incidence of adoption, intensity of adoption, and rate of adoption (Giller et al., 2015). Several studies have demonstrated that the incidence of adoption is determined by the ratio of people who adopt technology over time to the population size of the sample over time. Such studies are Corbeels et al., (2020); Ndah et al., (2018). Furthermore, Kassam et al. (2019) demonstrate that the intensity of adoption is dependent on the ratio between the amount of land used by the farmer and the total amount of arable land owned by him. Sunding and Zilberman (2017) define the rate of adoption of a technology in terms of the number of people who have adopted the technology over time compared to the size of the sample population. Adaptation refers to changing crops or planting dates due to changing weather patterns, for instance. It may be possible to adapt to climatic fluctuations using the following approaches and activities: Introducing high-yielding varieties, early maturing varieties, and altering nutrient and fertilizer applications in cold climates can be helpful, as well as identifying opportunities for soil conservation/ restoration/improvement (Landauer et al., 2019), and developing a contingency plan (Landauer et al., 2019) for temperature and rainfall risk mitigation.

Thornton et al. (2017) suggested that adapting to climate variability in the agricultural sector will require significant transformations. Li (2015) explains that successful adaptation influenced by awareness, education, gender, age, household capital, climate information, social capital, and agroecological location. A study by Harvey et al. (2014) found that climate variability makes smallholder farmers more vulnerable to droughts and floods. By practicing conservation agriculture or climate-smart farming, farmers can increase productivity. Based on the findings of Kibue et al. (2016), agricultural information and adaptation are correlated. Mango et al. (2017) found that group membership, education level, land ownership, and access to credit affect soil and water conservation. A smallholder farmer's decision to adopt can also be affected by his or her age, education, agricultural experience, and other socioeconomic factors (Wall, 2007). It is crucial to adapt to climate variability to mitigate its effects on crop production (IPCC, 2017).

There is a high dependence on agriculture among Ethiopia's population, which negatively impacts climate variability. To improve their livelihoods, communities must adapt to climate variability (Etana et al., 2020a). In addition, farmers have developed strategies to cope with precipitation variability and extreme weather events on their own. These strategies are in addition to those implemented by various organizations. According to Etana et al., 2020a), crop planting times should be changed, cropping practices adjusted, crop varieties diversified, drought-tolerant seeds planted, irrigation used, land management implemented, and migration encouraged.

Adapting to climate change requires an understanding of climate variability and variable weather conditions, according to Komba (2015). To achieve this, different varieties of crops should be planted, crop fields should be rotated, hybrid crops should be used, and water management practices should be used. Also, Mavhura et al. (2017) suggest planting early crops and limiting livestock in low-rainfall areas. It has been discovered that sustainable livelihood outcomes occur when economic, social, and environmental benefits are synergized (Haggar et al., 2021). In addition, Marie et al. (2020) stress the importance of soil and water conservation, mixed cropping, irrigation, and diversifying income sources when it comes to coping with climate change. Foguesatto et al., 2019) conclude that some adaptation technologies will require substantial capital expenditures.

Climate variability requires smallholders to utilize context-specific adaptation strategies. Akinnagbe and Irohibe (2015) describe how smallholders adapt their agricultural production practices to cope with climate change by growing drought-resistant crops, diversifying crops, changing planting schedules and crops, conserving soil moisture, increasing irrigation efficiency, and afforestation and agroforestry. In addition to these adaptation strategies, smallholders also use risk management strategies like climate-indexed insurance, livestock management, and conservation agriculture to manage their risks. As part of their coping and adaptation strategies, smallholder farmers use relatively cheaper methods, such as varying crop rotation periods and modifying sowing periods. Several smallholder farmers use irrigation systems, thereby changing sowing periods and diversifying crops as well as utilizing more complex or expensive techniques (Komba. 2015; Below. et al. 2012; Turpie et al. 2012). Climate-smart agricultural initiatives must be implemented to enhance agriculture's resilience and productivity.

2.8 Extension support and services towards the effects of climate variability.

Globally smallholder farmers are facing substantial challenges because of climate variability (Harvey, et al., 2018; Jamshedi, et al., 2019). Millions of people rely on the agricultural system for their livelihoods, but its limited ability to adapt to climate variability places it at risk. As a result of their reliance on rain-fed agriculture and natural resources, limited financial resources, and limited adaptive capacity, smallholder farmers are frequently adversely affected by environmental changes. Also, illiteracy and the low adoption of technology make it impossible to predict the likelihood of extreme weather events (Maponya et al., 2014; Ouedraogo et al., 2018; Phuong et al., 2018). Support systems have a significant impact on farmers' behavior (Mogomotsi et al., 2020). Most smallholder farmers, however, have no access to and are not aware of the support systems that are available to them, such as trainings, extension programs, farmer associations, and information (Eshetu et al., 2021).

In a study published by Ojo et al. (2021) farmers participating in support systems adopted more climate adaptation strategies. Smallholder farmers are expected to have access to climate-resilient technologies and activities as well as receive adequate knowledge and expertise to help them improve their farming methods. According to researchers, farmers are not effectively implementing and using adaptation and mitigation strategies to cope with climate variability (Olorunfemi et al. 2018). Because humans lack knowledge, awareness, and understanding, they have experienced adverse consequences because of climate variability (Olorunfemi and Oladele, 2018). Ncoyini et al., (2022) examined how sugarcane smallholder farmers use climate information to cope with extreme weather events and adapt to climate variability. The findings of this study have several practical implications. Climate information helps farmers adapt to current climate variability and plan for future climate change. Agriculture cannot adapt or cope appropriately and sustainably without such information. Aside from building farmers' resilience, climate information can also help them take advantage of favourable weather conditions. Smallholder farmers, however, are more vulnerable to climate extremes because they lack such information.

Farmer inventions and programs are disseminated by agricultural extension officers throughout the world. According to Anaeto et al. (2015), agricultural extension programs encompass all facets of agriculture, including timely information, connecting farmers with agricultural resources and credit facilities, and training on adaptive strategies, as well as transferring technology and providing education to farmers in all areas of agriculture (Olorunfemi et al. 2018).

Adapting to climate variability requires people to adjust their behaviours, knowledge, skills, and capabilities (Nnadi et al., 2013). These types of adjustments or learning are usually facilitated by formal and informal institutions. Further, extension services are essential for improving the food security of smallholders, households, and nations (Rickards et al., 2018). The authors of Khan et al. (2012) claim that agricultural extension services facilitate community development by improving farmers' knowledge and abilities related to agriculture. Moreover, they promote the adoption of new technologies by farmers and encourage them to change their attitudes towards farming. As noted by Bonye et al. (2012) and Swanson (2008), Agri-extension services play an important role in enhancing human and social capital, improving market access, and helping farmers sustain their crops. Danso-Abbeam and colleagues (2018) found that agricultural extension substantially improved the incomes and welfare of farmers in Ghana's northern region. A study conducted by Donkor et al. (2016) found that agricultural extension is highly effective in encouraging farmers to adopt soil improvement methods. Moreover, according to Afsar & Idrees (2019), agricultural extension is vital to enhancing farmers' awareness of locally appropriate adaptation strategies, so they are not adversely affected by climate change (Antwi-Agyei et al., 2018; Juhola et al., 2016). Wossen et al. (2018) also report that extension services play an important role in the success of farmers.

2.9 Theoretical framework for the study

In this section of the study, the researcher examines and presents theories related to the study, regarding smallholder sugarcane farmers’ perceptions of climate variability, as well as their potential behavioural responses in terms of adaptive strategies approaches. This study was based on Gibsons theory of direct perception, the theory of planned behaviour (TPB), and the Technology acceptance model (TAM).

2.9.1 Gibson's Theory of Direct Perception

In Gibson's theory of direct perception, perception is said to be based on what is visible right in front of our eyes, and humans perceive in response to their immediate surroundings. No prior experience or learning is required to fill in any perceptual gaps. We begin perceiving the world at birth. Based on Gibson's theory of direct perception, this study describes how perception, which extracts meaningful information from the environment to guide actions adaptably, improves as we gain experience, and acquire new ways to explore and develop perception-action systems (Gibson, 1984). Farmers who rely on direct perception can adapt their practices by observing environmental changes and responding to immediate weather conditions. This ability to perceive and react without relying solely on scientific data allows them to make timely decisions, such as altering planting schedules or choosing crops that are more resilient to current climate variations. Consequently, direct perception aids farmers in developing practical, experience-based strategies to cope with climate variability, enhancing their resilience and sustainability.

Interactions between humans and their environments are influenced by socioeconomic, cultural, political, geographical, ecological, and institutional factors (Eriksen et al., 2011). The theory asserts that individuals, social, economic, and ecological systems can and do adapt to changes in the environment (Smithers & Smith, 2009:19). To adapt effectively, we need adaptive capability, knowledge, skills, robust livelihoods, and alternative sources of income (IPCC, 2018a). Adger et al., (2003); IFAD, 2013) found that knowledge about climate variability, assets, technology access, institutions, policies, and perceptions contribute to adaptive capacity. Adaptation strategies are influenced by the perception of environmental factors, according to Smithers and Smith (2009). Different processes influence actions that follow perceptions of climate variability, including perceptions of risk associated with climate variability, resource endowments, cultural values, and institutional and political contexts. In addition, perceptions that climate variability exists or is occurring are not guaranteed to prompt effective adaptation responses (Weber, 2016). A key aspect of adaptation is modifying practices, processes, and systems to mitigate current and/or future adverse effects of climate variability and change (Eriksen et al., 2011).

Adaptations to climate change can either be planned or spontaneous, with the latter relying more on experience and prevailing conditions than predictions of future climate change (Smithers & Smit, 2009). According to Gibson's theory, an observer or interviewer uses their perceptual awareness to explore information freely. Fundamentally, it states that people can determine what is beneficial to their needs from information. This theory asserts that perception and action are directly related, as argued by Goodwin and Watkinson (2000). According to this study, human perceptions are influenced by many factors, including their beliefs, attitudes, and circumstances. According to Wu et al. (2020), the perceptions of humans are influenced by environmental factors. It is therefore the experience of humans that determines how they perceive their surroundings. There is a reasonable expectation that, even for smallholder sugarcane farmers, their perceptions are influenced by their experiences, beliefs, culture, norms, attitudes, and environmental factors. As part of this research study, we attempt to determine how climate variability is perceived and what adaptive strategies are utilized by smallholder sugarcane farmers in South Africa. As a result, Gibson's Theory is relevant to this study and aligns with its objectives.

2.9.2 The theory of planned behaviour.

Ajzen (1985) defines the Theory of Planned Behavior (TPB) as a theory that examines the psychological factors that influence human behavior and decision-making. This theory was developed by Icek Ajzen in 1985 as an extension of the Theory of Reasoned Action (TRA). Following the TPB, three major factors contribute to behavior: firstly, attitudes are the beliefs and feelings associated with a person's behavior. A second type of belief is normative beliefs, which are influenced by peers' or respected figures' perceived attitudes toward behavior or social pressures and norms that influence their behavior. A third factor is perceived behavioural control: specifically, how well they believe they can control their behavior and what resources are available to them (Otieno et al., 2016). TPB provides insight into how people's behavior can change. This is a very useful innovation theory that can be applied to the study of attitudes and perceptions. Considering that this model assumes that the behavior has been planned, it predicts contemplative behaviour (Ajzen, 2020). To explain innovation adoption, Ajzen and Fishbein's (1980) theory of planned behavior is commonly used. Individuals will engage in certain behaviours when they intend to do so.

Therefore, smallholder sugarcane farmer must first perceive the effects of climate variability and its consequences on their production, then decide how they will mitigate and adapt to these perceived effects, and then implement their decisions based on a set goal. Consequently, behaviours are a result of certain intentions. Perceptions of oneself and one's environment determine attitudes and subjective norms, which ultimately influence one's intentions. Rather than focusing on attitudes, the theory of planned behavior (TPB) emphasizes intentions. Behavioural intentions are influenced by motivational factors and reflect an individual's willingness to engage in certain behavior. Further, it considers the freedom of individuals to adapt, utilize, or not utilize technologies. The TPB can be used to assist researchers and practitioners in developing interventions and strategies that will promote positive behavior by understanding these psychological factors. Consequently, understanding how smallholder sugarcane farmers perceive climate variability-related adaptation strategies will have a significant impact on their willingness to embrace and implement these measures. Therefore, smallholder sugarcane growers' behavioural intention to adopt climate variability adaptation strategies will be influenced by their perception of the effects of climate variations on their livelihoods and production.

2.9.2 Technology Acceptance Model (TAM).

The Technology Acceptance Model (Davis, 1989), or TAM, posits that there are two factors that determine whether an innovation (Adaptive strategies) or system will be accepted by its potential users: (1) perceived usefulness, and (2) perceived ease of use. The key feature of this model is its emphasis on the perceptions of the potential user. That is, while the creator of a given technology product may believe the product is useful and user-friendly, it will not be accepted by its potential users unless the users share those beliefs. Davis (1989) established the TAM to examine the reception of technological innovations, drawing upon the theory of reasoned action. This process involves various factors that determine the level of acceptance or resistance towards the innovation (Königstorfer, 2008). These factors serve as a foundation for examining the influence of external influences on internal cognitive processes such as beliefs, attitudes, and intentions. The TAM posits that an individual's attitude towards a particular technology, such as adaptive strategies in this context, and their intention to use and associated technologies are influenced by their perceptions regarding the perceived ease of use and perceived utility of those practices (Ducey & Coovert, 2016). The concept of perceived usefulness was initially defined as the degree to which an individual believes that utilizing a specific innovative practice will enhance their sugarcane production or performance (Tubaishat, 2018). This implies that smallholder sugarcane farmers are more inclined to adopt adaptive strategies, when they perceive that the benefits of implementing these practices surpass those traditional methods of farming. These benefits consist of enhanced soil quality and increased yield production. In contrast, perceived ease of use was characterized as the extent to which an individual perceives that utilizing a specific technology would require minimal effort (Tubaishat, 2018). This suggests that smallholder sugarcane farmers are considerably more receptive to employing adaptive strategies and related technologies if they perceive them to be simpler to operate and inexpensive. On the contrary, adoption is likely to remain low if these practices are perceived as challenging to implement and expensive. This study centres around the utilization of adaptive strategies amongst smallholder sugarcane farmers with a particular emphasis on assessing the perceived effects of climate variability, the knowledge level regarding this available innovation to cope, and their adoption abilities of such practices, drawing from the Technology Acceptance Model. Government officials, extension administrators, and other stakeholders can use these recommendations to promote and scale up the adoption of these practices.

2.10 Conceptual Framework for the study

The conceptual framework of this study demonstrates that smallholder sugarcane farmers' perceptions of climate variability effects will depend on their knowledge level and socio-economic characteristics ultimately utilizing adaptive strategies. According to this study, human perceptions are influenced by many factors, including beliefs, attitudes, culture, knowledge level, norms, experiences, and socio-economic circumstances. Wu et al. (2020) say humans' perceptions are influenced by environmental factors. Human experience determines how they perceive their surroundings. The Conceptual Framework also assumed that humans learn to interpret their environment based on what they experience. Also, humans adjust their perceptions of situations according to the information, and knowledge level they possess. Therefore, they can take advantage of opportunities and adapt to their environment. Consequently, they can plan accordingly so that they can cope with the perceived effects of climate variability and adapt to their environment. The extent to which climate variability affects livelihoods and production will influence their decision to adapt. These strategies include improved technologies, risk management strategies, and diversification strategies. The conceptual framework also allows for developing policies to support smallholder sugarcane farmers in managing climate variability. Such policies should consider the knowledge level and socio-economic characteristics of smallholder sugarcane farmers and provide appropriate support. In addition, these policies should be tailored to the specific needs and challenges of each region.

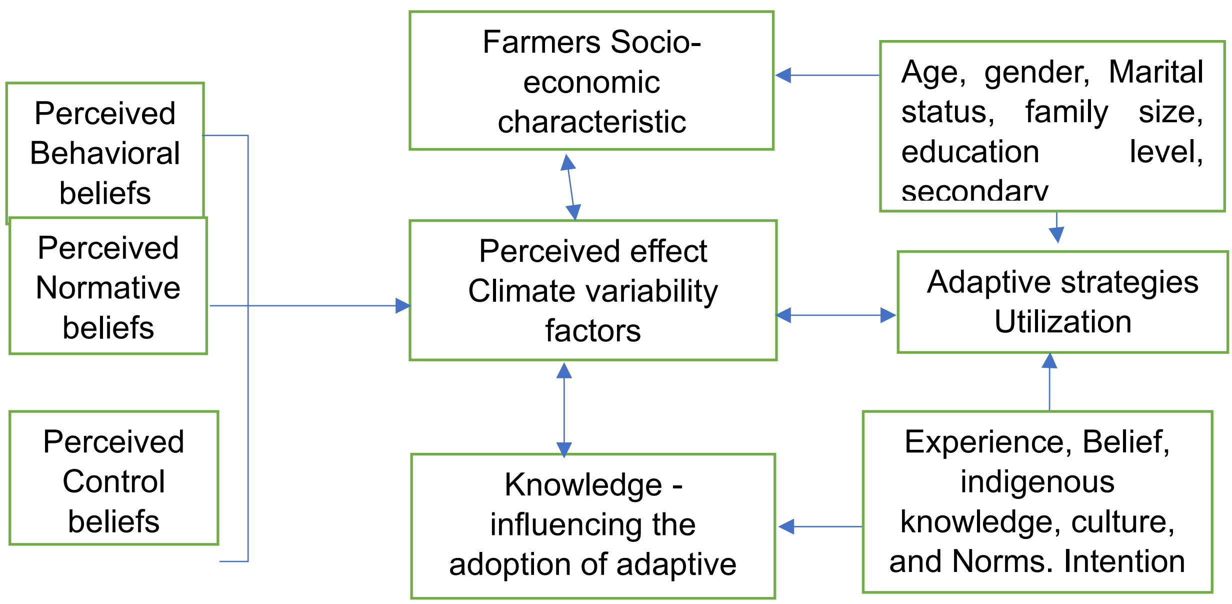


Figure 1: Conceptual Framework for the study

Source: Own Work November 2023.

2.11 Summary of the chapter

In this chapter, published literature on the effects of climate variability was reviewed. First, it focussed on the concept, causes and effect of climate variability on agriculture production. The effects of climate variability on smallholder farmers production. Next, the review focussed on literature exploring smallholder farmers perception, Smallholder farmers both Scientific seasonal climate forecasts (SSCFs) and indigenous knowledge regarding the effects of climate variability in developing countries. Also, there is literature on adaptive strategies utilized to mitigate/adapt from the effects of climate variability in the agriculture sector. Furthermore, the literature explored extension support and services regarding the effects of climate variability is reviewed., Lastly, the Gibson's theory of direct perception, the theory of planned behaviour (TPB), and the Technology acceptance model (TAM), as well as the study conceptual framework diagram are considered.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Chapter introduction

This chapter presents a discussion about issues of the research design and methodology implemented in the research. as well as the procedures used in the data collection process. Furthermore, it offers a detailed explanation of the research instrument, its validity and reliability, and the model that was employed during the data analysis phase.

3.2 Area of the Study.

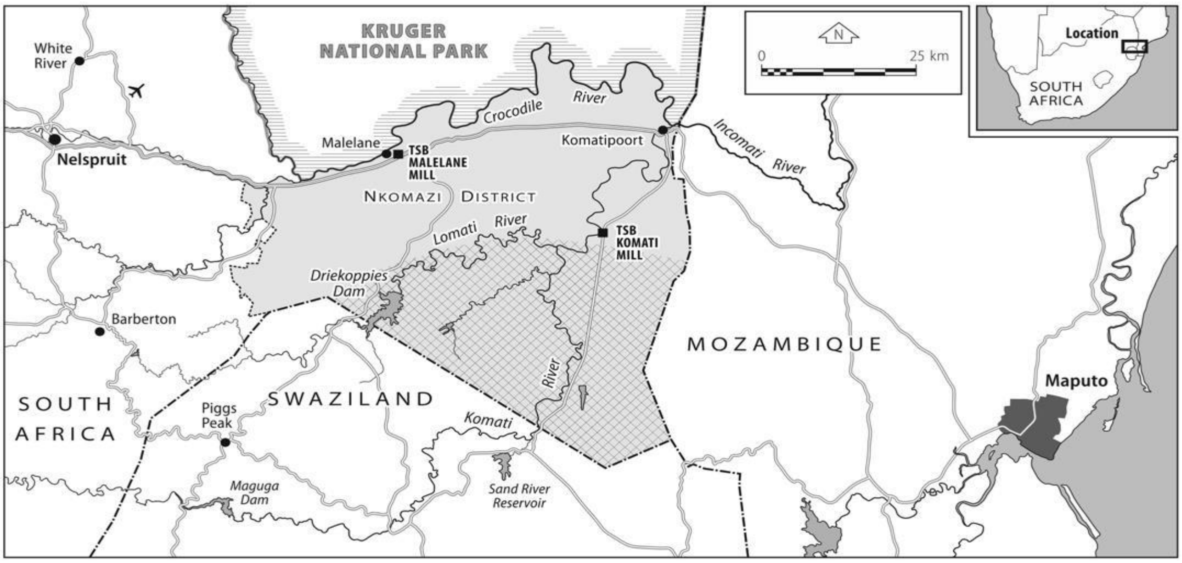
This study was conducted in the province of Mpumalanga in South Africa. The province is located in the eastern part of the country and is bordered by Swaziland and Mozambique on one side, and by KwaZulu Natal on the other. The district of Mpumalanga consists of four districts: Ehlanzeni, Bohlabela, Kangala, and Gert Sibande (Khwidzhili & Worth, 2020). Nkomazi Local Municipality is in the eastern portion of the Ehlanzeni District Municipality in the province of Mpumalanga. The municipality is in the northeastern part of the province of Mpumalanga. This study was conducted in Mpumalanga's Ehlanzeni District Municipality within Nkomazi Local Municipality. According to Khwidzhili & Worth, (2020) accounts that, females make up 50.5 percent of the provincial population, while males make up 49.5 percent. About 30.8 percent, of the residents, speak SiSwati, which is the language of Swaziland, while those speaking isiZulu people are estimated to be 26.4 percent; 12.1 percent speak isiNdebele.

The province has a population density of 46 people per square kilometre. In Mpumalanga, about 60 percent of the country's population lives in rural areas (Kgosiemang & Oladele 2012). In Mpumalanga Province, in the eastern part of the Ehlanzeni district between Swaziland (northeast of Swaziland) and Mozambique (east of Mozambique) coordinates latitude & longitude WGS84: (25°29'27.0"S 31°30'21.0"E) decimal degrees (-25.490833, 31.505833) is where Nkomazi Municipality is positioned. Besides provincial roads, there are rail lines and a major road (N4) that connects it to Mozambique (Nkomazi Municipality, 2006). City

Population (2016) reports that the municipality has a surface area of 4786.7 km2 and a population of 410 907, with 1.6% whites and 97.7% blacks. There are 47.3% of males and 52.7% of females in the city (City Population, 2016). There are 33 wards in Nkomazi Local Municipality. The area of the municipality is 4 787 square kilometres, which is about 4% of the total geographical area of the province, about 23%. In 2016, the municipality's population was 410 907 (Census, 2016).

The Nkomazi Local Municipality is Agribusiness, forestry, and tourism are among the main economic activities in the Nkomazi area, as well as the predominant land-use pattern. A subtropical climate characterizes the Nkomazi local municipality. A September 2005 survey conducted by Statistics South Africa reveals that agriculture was the fourth-largest formal employer in the province. There are two small towns in this Municipality called Komatipoort, which is about 8km from the Mozambique border gate at Lebombo. Malelane is 45km from Swaziland at Matsamo. Within Nkomazi there are three rivers, the Crocodile River in the highlands, the Lomati River in the lowlands, and the Nkomati River in the agro-geographic zones which provide agricultural resources and livelihoods for the residents.

The temperate in winter and hot and humid in summer climatic conditions in this municipality are suitable to produce most crops throughout the year. Consequently, this area has a high agricultural potential, capable of producing several different crops all year round under irrigation (IDP, 2017). There are two sugar mill areas owned by RCL foods called Komati and Malelane Mills. Growers sell their sugarcane crops to these mills from April to December annually. Approximately 88% of Nkomazi households have incomes that are less than R 1000 per month, which translates into a 50% unemployment rate for the economically active population. Based on the CRDP survey, 90.4% of households earned less than R1000.00 per month in the southern region while 36.8% were without income. Five (5%) of the population in the Nkomazi area, earns less than R 3 500.00 per month; in the Onderberg area it rises to 12%. (Census, 2016).



Shaded area: hatched portion was previously administered as KaNgwane homeland.

Figure 2: Map of Mpumalanga province, showing the Nkomazi district municipality.

Source: James and Woodhouse, 2017.

3.3 Research design

Research design is an approach that a researcher seeks to use to prove a hypothesis or answer a research question (Mabunda, 2017). This study adopted a mixed methods approach with an aim to determine how smallholder sugarcane farmers in the local municipality of Nkomazi perceive the effects of climate variability and their use of adaptive strategies. Creswell (2018) describes mixed methods of research as a method and methodology of collecting, analyzing, and integrating quantitative and qualitative research in a single study. As this method combines both quantitative and qualitative approaches, it provides a more comprehensive understanding of the research problem than either approach would provide on its own (Creswell, 2018). Moreover, Terrell (2011) attests that the use of a mixed method approach within a single study will aid the researcher to cross-validation, confirm or compare, strengthen, and corroborate collected and analysed results. Data was collected concurrently and integrated during interpretation phase using the concurrent triangulation strategy to strengthen knowledge claims or cross validation of collected data (Creswell, 2008).

3.4 Sampling procedure and sample size

A Two-stage sampling procedure was used in this study. In the first stage, a purposive sample was used to select smallholder sugarcane farmers famers in the study area producing and selling sugarcane to Nkomati Mill on less than 10 hectors of land. In the second stage, a simple random sampling was then used to select 205 participants from the total population of 421 smallholder sugarcane farmers. A simple random sampling method was used to ensure that all participants had an equal chance of being included in the sample (Owino, Odondo & Obange, 2018). The Slovin's formula was then introduced to calculate the appropriate sample size from 421 population, at a 95% confidence level and a 5% margin of error. Slovin's formula is a statistical formula used to calculate the sample size required for a population, based on the desired level of precision and confidence (Anugraheni, Izzah & Hadi, 2023).

The formula used by the online calculator is as shown below:

A Slovin formula

Calculates sample size (n) given population size (N) and margin of error (e).
- it's a random sampling technique formula to estimate sampling size
- It is computed as n = N / (1+Ne2).

whereas:

Formular: **n=**

Where: **n**= Sample Size **(205)**

N= Population Size of smallholder farmers **(421)**

e= Desired Margin of Error **(0.05)**

Therefore, the sample size that was selected for the study was two hundred and five (205) registered smallholder sugarcane farmers.

3.5 Data collection

3.5.1 Data collection instruments

Data was collected using a mixed method research approaches to validate results, restrict contradictions, and narratively corroborate research findings. Moreover, data was collected concurrently and integrated during interpretation phase using the concurrent triangulation strategy to strengthen knowledge claims or cross validation of collected data (Creswell, 2008). A structured questionnaire was developed as the survey instrument to eliciting data (face-to-face) in the study areas. Taherdoost, (2022) defines a questionnaire as an-uniform research instrument that consists of a predetermined set of questions intended to collect statistically significant data from one or more participants regarding a specific subject matter. Additionally, the researcher was granted permission to record these interviews and carefully transcribing the participants responses. Prior to the data collection process, four (4) enumerators were trained to help with the collection of data from 205 study participants.

The survey instrument was divided into four (4) sections, each structured to provide sufficient data on a specific study objective. Each of the objective variables was operationalized and measured at the nominal, ordinal, and interval levels as appropriate. The first section of the data collection instrument provided data on the socio-economic demographics of smallholder sugarcane farmers in the study area. The second section was used to elicit data on the perceptions of smallholder sugarcane farmers regarding climate variability factors influencing sugarcane production. The third section elicited data on knowledge of smallholder sugarcane regarding climate variability adaptive strategies. The fourth section provided information on the adaptation strategies utilized by these sugarcane farmers.

Furthermore, a qualitative data collecting technique was also used to obtain more detailed information on the farmers' perception on climate variability and the utilizations of these adopted strategies by conducting an in-depth (face-to-face) interview with ten (10) key informants using a semi-structured interview. Moreover, to ensure validity and reliability, both structured and semi- structured questionnaires were pre-tested by the researcher and trained enumerators before being administered to the selected respondents.

3.5.2 Measurement of Variables

Some of the key variables employed in the study were measured, as shown below: Perception on the effect of climate variability: A series of statements about the probable effect of climate variability factors on sugarcane production was presented to them, and their agreement or disagreement with these statements was rated on a 5-point Likert scale of: strongly agree (5), agree (4), undecided (3), disagree (2), strongly disagree (1). Knowledge regarding climate variability adaptive strategies: A series of statements about the probable knowledge of climate variability adaptive strategies was presented to them, and their responses to these statements were captured as Yes, No and Not sure. Every response that was correct was coded as 1 and incorrect response was coded as (0).

Adaptation Strategies Utilized regarding Climate variability: A list of items relating to climate variability adaptation strategies utilizable in sugarcane production was presented to the respondents and they were asked to indicate or specify those that they use on their farms. Their responses were rated on a three-point use scale of Not utilized (1), moderately utilized (2), and Utilized (highly (3).

3.6 Validity and Reliability of instrument

The term "validity" refers to ensuring that the data collection instrument is measuring what it claims to be measuring. The instrument was subjected to face validation and close examination by the university ethical committee, university supervisors and co-supervisor as well as agricultural extension professionals, who ensured that the questionnaires measured what they are intended to measure and gave their expert opinions and advice.

The term "reliability" refers to the ability to demonstrate that the data collection instrument is consistent. A pre-test of the instrument was conducted in a community in Nkomazi municipality utilizing the test-re-test method of reliability. This was done to ensure the adequate consistency of the instrument and avoid ambiguity. Ten (10) questionnaires were administered to the same respondents twice, within an interval of two weeks, and the collected data were analyzed, and the respective data sets correlated with one another. A high correlation coefficient of 0.87 was obtained which showed that the instrument was adequately consistent. According to Heale and Twycross (2015), a highly consistent and reliable instrument has a reliability coefficient of 0.80 or higher.

3.7 Analysis of Data

Survey data were descriptively and statistically analyzed (e.g. frequency, mean, ranks etc.) using IBM SPSS software version 28. The descriptive statistics mentioned were adopted to analyze the research objectives. The data analyzed were visualized and presented in the form of tables, frequency counts, percentages, means, ranks, and pie charts. Descriptive analyses were used to describe a specific phenomenon and studies situations to understand and describe a particular behavior. Furthermore, multiple linear regression analysis adopting the ordinary least square approach was employed as an inferential statistic to analyze the hypotheses proposed for the study. Comparing smallholder sugarcane farmers production output from 2020 to 2022 growing seasons, a paired sample t-test was carried out. The respondents' socio-economic characteristics were the independent explanatory variables used in the regression model while the computed adapted strategies utilization by the respondents served as the dependent variable in the model (Table 1). Ten (10) adaptive strategies were presented to smallholder sugarcane farmers, and they were asked to indicate or specify those that they use on their farms. Their responses were rated on a three-point use scale of Not utilized (1), moderately utilized (2), and Utilized (highly (3). Based on this rating the maximum score obtainable by any farmer is thirty (30) and the minimum score is ten (10). Following the precedence of Abegunde et al. (2022), a composite score analysis was used to generate a climate variability adaptation strategies utilization score for each respondent. The score computed served as a proxy to represent the climate variability adaptation strategies using the score for each respondent which was then fitted as a dependent variable in the multiple linear regression analytical model that was used to determine the socio-economic factors influencing respondents' use of climate variability adaptation strategies.

3.7.1 Model specification

The farmers' socioeconomic variables such as their age, gender, education level, farm size, years of experience served as the independent/explanatory variables in the model.

The explicit formula of the model is:

$P = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + \beta 8X8 + \mu$

Where P is the smallholder sugarcane farmer's adaptation strategies utilization index.

B represent the vector of unknown coefficients to be estimated, X is a vector of hypothesized explanatory variables which consist of farmers socioeconomic characteristics and μ which is the normally and independently distributed random error term. The qualitative data collected from 10 key informants were analysed thematically using direct quotes from the respondents. According to Bryman (2012), such information helps to corroborate and validate the reliability and authenticity of the quantitative data collected. Furthermore, Newing (2011) states that key informant data is used to summarize key themes, and they are illustrated by direct quotes, elaborating on the experiences and views of respondents that the author believed were relevant and authentic, in the case of smallholder sugarcane farmers in this study.

Table 1: Explanatory variables used to predict smallholder sugarcane farmers utilization of climate variability adaptation strategies.

Explanatory variables	**Responses**
Gender	Categorical (Male, female)
Age	Continuous
Marital status	Categorical (Married, Unmarried)
Family size	Continuous
Level of education	Categorical (Primary, Secondary, Tertiary ABET)
Secondary occupation	Categorical (Yes, No)
Farming experience in years	Continuous
Farm size	Continuous

3.8 Ethical consideration statement

The researcher applied for ethical clearance from the University of Mpumalanga Ethical Clearance Committee and adhered to all necessary ethical and professional standards throughout the study. All prejudices, biases, and attitudes that would not convey objectivity and neutrality were avoided. The following are some of the ethical issues that were considered in this study:

Anonymity and Confidentiality: Before the questionnaire administration, the researcher asked for the consent of the respondents and assured them of the utmost confidentiality.

Respondents were allowed to remain anonymous because their identities were not required on the questionnaire. The information gathered from the responders was also held in strict confidence. Moreover, the questionnaires were administered at locations that were convenient to the respondents and translated on their native language.

The voluntary participation factor was adhered to by signing an informed consent form before the interviews, which described the purpose and rationale for completing the research questionnaire. Participants were given the option of participating or not participating in the study. If they did not feel comfortable answering the questions, they had the option of withdrawing at any time.

Beneficence and non-maleficence: Throughout the study, the researcher prioritized the respondents' well-being. The study did not engage in anything hazardous or hurtful to the respondents' health or interests in any manner. Respondents were also told that they had the right to seek the study findings after it has been finished to use the findings to enhance their enterprise and livelihoods.

3.9 Chapter summary

This chapter presented a comprehensive overview of the survey area as well as the research methodology used. A mixed method research design was used to profile the perceived effects of climate variability, and adaptive strategies utilized amongst smallholder sugarcane farmers in the study area. Moreover, the chapter provides general descriptions of the sampling techniques, the instruments employed in information collection, the instruments for ensuring validity and reliability, and the data collection procedures. Two-stage sampling procedure was used in this study. A structured questionnaire to collect data from 205 respondents, was adopted for the study. Also, semi-structure questionnaires were administered to 10 key-informant to obtain more detailed information on the farmers perception on climate variability. To analyze the study objectives and hypotheses, descriptive and inferential statistics were adopted. Comparing smallholder sugarcane farmers production output from 2020 to 2022 growing seasons, a paired sample t-test was carried out. The multiple linear regression model, which is best suited for analysing data to reject or accept a hypothesis, was explicitly articulated in the chapter.

CHAPTER FOUR
RESULTS AND DISCUSSION OF DESCRIPTIVE ANALYSIS

4.1 Introduction

This chapter presents the findings and discussion of the data analysis results. It is fragmented into sections, focusing on each specific study objective. The various sections of the study report on the results and discussion of the socio-economic characteristic of the smallholder sugarcane farmers, the perceived effects of climate variability on sugarcane production, the knowledge of smallholder sugarcane farmers regarding climate variability and adaptive strategies, and the adaptation strategies utilized in the study areas. The results are presented mainly in the form of tables and graphs. The results were discussed and where viable compared and linked to literature.

4.2 Socio-economic characteristics of smallholder sugarcane farmers

4.2.1 Results and discussion of the socio-economic characteristic of smallholder sugarcane farmers regarding.

The results from Table 2 shows that about three-quarters (74%) of smallholder sugarcane farmers were aged from 50 years and above, while 25% were between 24-49 years, and 1% were ≤ 23 years old. The means age among the respondents was 58.03 years, with a standard deviation of (13.23). This indicates that most of the sugarcane farmers in the study area though still economically active were in their middle-ages and are approaching their less productive years. According to Obasi et al. (2013), an aging farmer’s population can have a significant negative impact on the efficiency and sustainability of agricultural production in an area. Hence, there is a need to encourage increased participation of the younger generation in sugarcane farming enterprises to secure the future of agriculture and ensure food security in the area.

Furthermore, the results from Table 2 indicate that 81% of the respondents had a family size ≤ 5 and above persons, while the remaining 19 % had ≤ 4 persons in their households. The mean household size found among the smallholder sugarcane farmers in the area is 7 persons with a standard deviation of 3 persons. This implies that, sugarcane farmers in the area generally have a large household size and thus have the privilege to make use of some of their household members as family labour which will help in saving costs on hired farm labour. According to Olorunfemi et al. (2014), household size among smallholder farmers is generally linked to the source of labour with a lot of farmers with large household sizes usually finding their family members helpful in agricultural activities. The above finding is in line with that of Baloyi (2011) who also found that the use of family labour can reduce labour costs. Farmers with a large family size. who use family labour to harvest their produce are more likely to increase their production compared to those who used hired harvesting labour (Baloyi, 2011). Furthermore, Kolleh (2016) attest in his findings that, a large household size offers the farmers greater access to family labour, which is expected to reduce the farm costs and enhance maximum output.

The findings in Table 2 also reveal that a little below half (45%) of the smallholder sugarcane farmers had attained a secondary educational level, less than one third (25%) had primary education, and few (8.8%) had tertiary education, while a small number (1.2%) had been in ABET education. Only (20%) of the farmers had no-formal education. This is a good attribute as the high level of formal literacy among the farmers is expected to enhance their level of exposure, innovativeness, and information-seeking on issues relating to climate variability and the various strategies they can utilize to adapt and mitigate its effect on sugarcane farmers. This result agrees with Ndlovu et al. (2021) who stated that an increase in the level of formal education among smallholder farmers usually influences their decision-making and use of farm innovative strategies.

This is consistent with the findings of Nefale (2016) stating that, the effect of educational level plays an important role in enhancing the cognitive, problem-solving, innovative, and decision-making abilities of the farmers. Mohlala (2020) also, attest that the level of education has a significant impact on the ability of farmers to be trained to deal effectively with their problems. Further, Mugula and Mkuna (2016) and Deressa et al. (2008) report that experienced and educated farmers possess more skills and knowledge about adaptive measures and climate change. According to Ibrahim et al. (2015), farmers' literacy level affects their understanding of climate change and how to adapt. Those farmers who are educated respond to climate change risks by making at least a few adaptation choices (Maddison, 2007). In farming, education plays an important role in raising awareness, since trained individuals can search for information on their own.

The results in Table 2 further indicate that, majority (85%) of smallholder sugarcane farmers had secondary occupations, which mean majority of sugarcane farmers have also diversified into non-farm livelihood activities to ensure sustainable livelihoods. Whereas on a few (15%) of the farmers were relying on sugarcane farming as their only source of generating income to sustain their livelihood. This is in line with Balana et al. (2021) who address that smallholder farmers' involvement in livelihood diversification strategies should be encouraged to prevent their vulnerability to food insecurity and poverty in case of their exposure to risk and shocks which negatively affect their farm enterprise as this will guarantee their livelihood sustainability. Thus, Makuvaro et al., (2017) indicated that farmers engaging in mixed farming, targeting to yield a wide range of crop and livestock production to improve and sustain their livelihoods. However, the increasing climatic and economic risks associated with smallholder agriculture, diversification in both farm and off-farm livelihood strategies is being encouraged. In fact, non-farm jobs are essential to diversify income sources and improve the livelihoods of members (Mzuyanda, 2014).

Table 2: Frequency distribution of the smallholder farmers according to age, family size, level of education and secondary occupations.

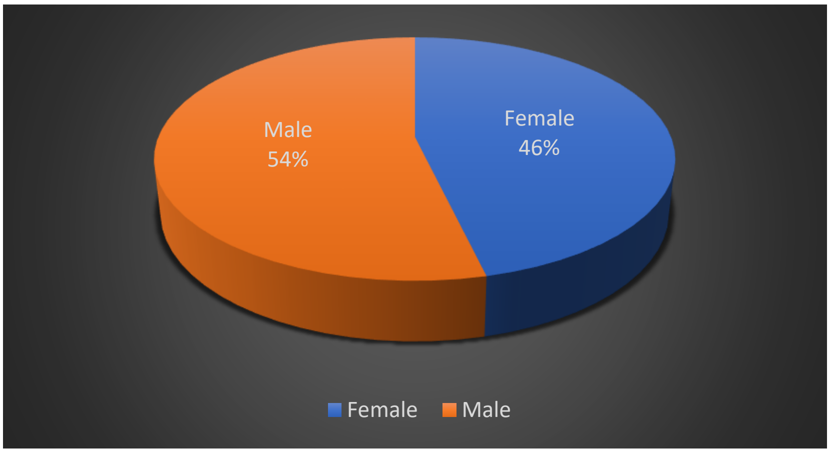
Characteristics		Frequency	(%)	Mean (SD)
Age (Years)	≤ 23	2	1.0	58.03 (13.23)
	24 – 49	52	25.0	
	50 – 79	110	53.9	
	70 and above	41	20.1	
Family Size	0 – 4	38	18.6	7.18 (3.164)
	5 – 10	144	70.2	
	11 and above	23	11.2	
Level of education	No formal education	41	20.0	
	ABET	3	1.5	

	Primary	51	24.9	
	Secondary	92	44.9	
	Tertiary	18	8.8	
Secondary occupation	Yes	174	84.9	
	No	31	15.1	

Source: Field Survey, 2023.

4.2.2 Frequency distribution according to the respondents Gender.

Figure 3 show that (54%) of smallholder farmers were males, while the remaining (46%) were females. This result indicates a bit higher number of males participation than females' in sugarcane farming activities in the study area, as just a slight difference exists between males and females. The slightly higher number of male farmers may be attributed to the hard work involved in agricultural activities. In a study conducted by Oduniyi (2013), it was found that female farmers are less active in the agriculture industry than male farmers. Coster and Adeoti (2015) report that male authority is associated with strenuous farming due to the high amount of physical labour involved. Contrary to men, women generally have limited access to critical agricultural inputs, which disadvantages their participation in the farming process. The results of this study are also in agreement with Alston et al. (2018), who observed that a slightly equal distribution of farm workers enables optimal efficiency and sustainable production on the farm

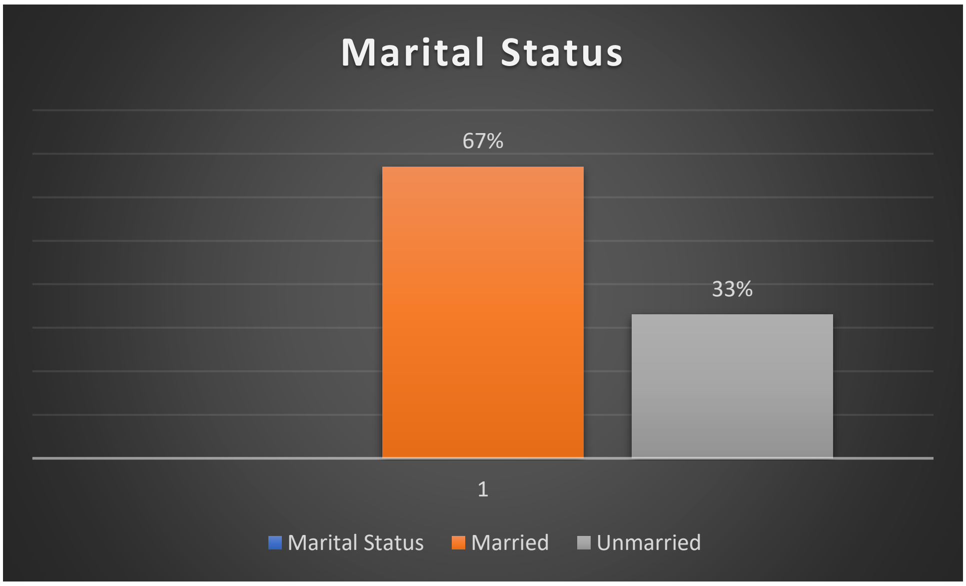


Source: Field Survey, 2023.

Figure 3: Gender distribution of the smallholder farmers

4.2.3 Frequency distribution according to the respondents on their Marital Status.

Figure 4 results reveals that 67% of smallholder sugarcane farmers are married and 33% indicating being unmarried. This implies that most farmers were married. Any member of a farming household may have a greater understanding of the effects of climate variability, which may be beneficial. This is in line with Abdul-Hanan's (2017) findings, which indicate that marital status was a significant predictor of contour farming and mulching adoption. It was attributed to the fact that household decisions were made jointly, and responsibilities were shared. Babalola and Olayemi (2013) also found that marital status was significantly associated with the adoption of land management practices. Consequently, married couples are more likely to adopt sustainable farming practices, probably because of the fact that they share decision-making responsibilities and household management responsibilities.



Source: Field Survey, 2023.

Figure 4: Marital Status frequency distribution of the smallholder sugarcane farmers

4.2.4 Results and discussion of the socio-economic characteristic of smallholder sugarcane farmers regarding (farming experience, farm size, and means of land ownership).

Table 3 below shows the socio-economic characteristic of smallholder sugarcane farmers regarding farming experience, farm size, and means of land ownership.
The results revealed that of the smallholder sugarcane farmers (81%) had ten (10) years and above farming experience. Whereas (19%) of farmers had less than nine (9) years of farming experience. The overall average farming experience of 18 years evident across the entire study area is an indication that smallholder sugarcane farmers participating in the study are on their midst age and older farmers with decade's experience in farming. This indicate that most sugarcane famers are well capacitated with skills and knowledge in various aspects of farming and group dynamics so that they can channel their energy and innovativeness in adapting to climate smart strategies available and making good farming decisions that will be sustainable and enhance their livelihoods. This implies that farmers are knowledgeable about their farming sector. Ibrahim et al. (2015) and Madisson (2007) found that experience is positively correlated with farmers' productivity, as well as their ability to perceive climate variability sooner. The findings of Sebeho (2016) are also in accordance with the fact that farmers' experience in farming is crucial for making sustainable decisions.

Furthermore, the results in Table 3 regarding the farm size is presented in hectares. It was measured by portions of land under cultivation. Most (86%) of the smallholder sugarcane farmers had a farm size of ≥ 5.1 hectares of land and above. Whereas minor (14%) of farmers had a farm size within the range of 1 hectare to 5 hectares. The overall mean farm size of 7.19 hectares and standard deviation of 1.72 indicates that the farmers in the study area have quite sizeable areas of farmland that they use for sugarcane production purposes. Which, if properly managed could contribute to sustainable and improved farmer livelihoods. Nnadozie et al. (2015) and Anigbogu et al. (2015) stated that the relationship between farm size and output implies that the size of the farm holding affects output; that is, the smaller the size of farm, the smaller the output and consistently the farm income. Thus, Nnadi et al. (2018) shared the same sentiment that increased farm sizes could mean an increased resource base and investment. Therefore, strategies increasing farm size would yield a corresponding increase in the commercialization of sugarcane farmers' cooperatives. Moreover, the results in Table 3 show that all (100%) of the smallholder sugarcane farmers indicated that they own the land they use for their farming activities. This implies that these categories of farmers will have access to the benefits that are attached to land ownership such as using it for security to access credit facilities. According to Wang et al. (2022), smallholder agriculture is most times characterized by insufficient security of land tenure and free rider problems associated with communal land ownership which are considerable obstacles to agriculture. As a result, the farmer might be able to adopt a new farming method since there are no restrictions on privately owned land.

Table 3: Frequency distribution of the respondents according to farming experience, farm size, and means of land ownership.

Characteristics		**Frequency**	**(%)**	**Mean (SD)**
Farming Experience (Years)	≤ 9	40	19.0	17.90 (8.36)
	10 – 20	80	39,3	
	21 and above	85	47.1	
Farm Size (Hectares)	≤ 5	29	14.3	7.19 (1.72)
	5.1 – 10	176	85.7	
Means of land Ownership	Own land	205	100.0	

Source: Field Survey, 2023.

4.2.5 Respondent characteristics based on their water source, organization membership, and Extension services.

The results on Table 4 indicate that (100%) of smallholder sugarcane farmers draws their water from rivers as their source to irrigate sugarcane and other farming activities. This implies that these categories of farmers will be able to irrigate they plant according to the water requirements and perform other agricultural activities in the farm, than those practising dryland farming depending on rainfall. Findings in Table 4 reveal that all (100%) the smallholder sugarcane farmers belong to various organisation namely, RCL foods, DARDLEA, SAFDA and other inputs suppliers who gives great support and benefits to this farmer group. This implies that most of these farmers have the privilege of benefiting from the various collaborative efforts and group dynamics that are derivable from being part of associations such as farmer groups and cooperative societies. Some of such benefits include benefitting from information that could improve their farming techniques, better access to government support, and getting more affordable inputs from Agri-hub. As stated by Barongo (2021), an increase in the number of years of group membership leads to increased understanding, improved group dynamics and an enhanced capacity to solve one another’s problems. Furthermore, Hlatshwayo et al. (2021), agrees that farmers’ memberships of groups increase their access to information important for production and marketing decisions. Also, farmers that are involved in organization and groups are expected to generate more income as compared to the ones that farm on their own unless the individual’s farm has enough capital, skills, and labour that is necessary for their farming activity. According to Sechube et al. (2020), farmers belonging to groups or organisation usually benefit more from extension services, and government programs as such are more easily facilitated in groups than with individual farmers.

Moreover, the results on Table 4 indicate that all (100%) of smallholder sugarcane farmers receive visits from extension officers in the study area. Smallholder farmers' access to extension services has been seen to influence their awareness and utilization of agricultural technologies and innovations such as climate change adaptation strategies. According to Mango et al. (2017), extension officers are supposed to ensure farmers are assisted with adequate access to the right and timely information to make informed farm decisions that will improve their productivity and livelihoods. According to FAO (2016), their participation is expected to increase farmers' access to climate-resilient technology and activities, as well as providing enough awareness and expertise to help smallholder farmers improve their production. Farmers who are exposed to agricultural extension services are more able to make educated choices about improving farming activities. Thus Mehar et al. (2016), went on and support his discoveries by stating that farmers who are exposed to extension programs are expected to choose agriculture activities such as rotating cropping over non-agricultural practices such as taking on a second job or reducing their food consumption.

Table 4: Frequency distribution of the respondents according to source of water for irrigation, farmers membership and extension services.

Characteristics		**Frequency**	**(%)**
Source of water for sugarcane irrigation	River	205	100
Membership of farmers organization	Yes	205	100
	No	0	--
Extension services	Yes	205	100
	No	0	--

Source: Field Survey, 2023.

4.2.6 Estimated sugarcane production output in tons from 2020,2021 and 2022.

The results in Table 5 reveals the total sugarcane production output experienced by smallholder sugarcane farmers in 2020. Over half (61%) of farmers had a production range from 501-1000 tons of sugarcane output in 2020. However, 35% of sugarcane farmers produced an-output of ≤ 500 tons on the same growing season, and moreover 3.9% of sugarcane producing farmers managed to produce an-output of ≥ 1001 and above tons on that same growing season in 2020. The overall mean of sugarcane production output in 2020 was 603 tons and standard deviation of 198.9. Moreover, the results in Table 5 reveals the total sugarcane production output experienced by smallholder sugarcane farmers in 2021. The findings showed that 60% of the farmers had ≥ 501-1000 tons of sugarcane production output in 2021 with a slightly drop of 1% from a previous year. However, 35% of sugarcane farmers produced an-output of ≤ 500 tons on the same growing season showing no output increase, and moreover 4.9% of sugarcane producing farmers managed to produce an-output of ≥ 1001 and above tons on that same growing season in 2021 showing a 1% increase in production output from this category of farmers. The overall mean of sugarcane production output in 2021 was 585.22 tons and standard deviation of 193.9.

Additionally, the results in Table 5 also reveals the total sugarcane production output experienced by smallholder sugarcane farmers in 2022. The findings showed that more than half 54.4% of the farmers had ≥ 501-1000 tons of sugarcane production output in 2022 with a marginally drop of 5.6% from a previous year. However, 42.43% of sugarcane farmers produced ≤ 500 tons during 2022 indicating an increase in numbers of farmers producing less sugarcane output during this growing season, and 3.4% of sugarcane producing farmers managed to produce an-output of ≤ 1001 and above tons on that same growing season in 2022 showing a significant decline of 1.5% in production output from this category of farmers. The overall mean of sugarcane production output in 2022 was 571.9 tons and standard deviation of 197.4. This corroborates the findings of RCL Foods (2018) reports a drastic decline in the sugarcane production among smallholder farmers in Nkomazi local municipality in addition, Metiso and Tsvakirai (2019) also agrees that smallholder sugarcane farmers especially in the Mpumalanga province continue to experience production decline

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Table 5: Frequency distribution of the respondent's estimated sugarcane production output in tons from 2020, 2021 and 2022.

Characteristics		**Frequency**	**(%)**	Mean (SD)
Production output 2020	≤ 500	72	35.1	603.0 (198.9)
	501-1000	125	61.0	
	1001 and above	8	3.9	
Production output 2021	≤ 500	72	35.1	585.22 (193.9)
	501-1000	123	60.0	
	1001 and above	10	4	
Production output 2022	≤ 500	87	42.43	571.9 (197.4)
	501-1000	111	54.14	
	1001 and above	7	3.41	

Source: Field Survey, 2023.

4.3 Results and discussion on the Perceived effects of climate variability on sugarcane production aspect of the study.

The results from Table 6 showed the perceived effects of climate variability on sugarcane production aspect of the study. The respondents were asked to indicate their perceived effects on a 5-point Likert-type scale of strongly agree (5), agree (4), undecided (3), disagree (2), and strongly disagree (1). The actual mean is 3 due to the rating scale and a mean of greater than 3 signifies a high level of perception while a mean below 3 is deemed a low perception level by the farmers. Using mean scores to rank smallholder sugarcane farmers' perception of the effects of climate variability based on their level of agreement with the various perception statements posed to them, smallholder sugarcane farmers overwhelmingly exhibited a high level of perception on the perception constructs as the means of all the statements were above the benchmark of 3. Some of the prominent statements the smallholder sugarcane farmers agreed were the resultant the perceived effects of climate variability on their sugarcane farms were “PS1 (MS=4.59) which ranked first, climate variability is responsible for the change in temperature. PS2 (MS=4.55) which ranked second, climate variability can cause soil degradation and erosion. PS8 (MS=4.55) which ranked third, Increased temperature which results from climate variability decreases sugarcane production. PS10 (MS=4.53) which ranked fourth, Intense drought conditions negatively affect sugarcane production and yield.

The results indicate that most of the respondents perceived intense change in temperature as the major effect on their sugarcane production and livelihoods as it was ranked first. This shows that smallholder sugarcane farmers were greatly affected by the intense high temperatures in the study area, as it affected their production and plant growing seasons. Furthermore, Soil degradation and erosion were ranked second. Decrease in sugarcane production was ranked third. Intense drought conditions negatively affect sugarcane production and yield which ranked fourth. This implies that several climate variability factors pose a significant risk to farms leading to production and yield decline when they are not correctly monitored and well managed. These variables may be divided into three categories: biological, environmental, and technological (Noya et al., 2018).

To substantiate the quantitative finding, a qualitative approach was employed. *During the key-informants interview participants indicated evidently that "they had observed changes in some of the climatic variables (rainfall, temperature, humidity, wind) in the study area. Moreover, "participants also revealed clearly, that persisted drought and rainfall pattern variations negatively affect the growth and development of sugarcane leading to loss of productivity drastically." Furthermore, "it was said that excessive rainfall has resulted in loss of topsoil and manure due to flooding, and water logging effects are leading to land degradation."* Similarly, Malhi et al. (2021) reported that smallholder farmers in Punjab, India perceived climate change as having a detrimental effect on their crops and livelihoods. Smallholder farmers in the region are particularly vulnerable to climate variability.

Table 6: Distribution of the respondents according to the Perceived effects of climate variability on sugarcane production in the area.

Statements	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Means score	Rank
Climate variability is responsible for the change in temperature.	124(60.5)	77(37.6)	4(2.0)	0(0.0)	0(0.0)	4.59	1
Climate variability can cause soil degradation and erosion	117(57.1)	84(41.0)	4(2.0)	0(0.0)	0(0.0)	4.55	2
Increased temperature which results from climate variability decreases sugarcane production.	119(58.0)	79(38.5)	7(3.4)	0(0.0)	0(0.0)	4.55	2
Intense drought conditions negatively affect sugarcane production and yield	112(54.6)	89(43.4)	4(202)	0(0.0)	0(0.0)	4.53	4
Water stress caused by climate variability reduces herbicides efficiency in sugarcane	108(52.7)	94(45.9)	2(1.0)	1(0.5)	0(0.0)	4.51	5

Climate variability is responsible for the unpredictable rainfall intensity	100(49.3)	100(48.8)	3(1.5)	1(0.5)	0(0.0)	4.47	6
Soil fertility on sugarcane farms is reduced by climate variability	103(50.2)	97(47.3)	4(2.0)	1(0.5)	0(0.0)	4.47	6
The drying of river, dams and other water bodies are resultant effect of climate variability	98(47.8)	101(49.3)	6(2.9)	0(0.0)	0(0.0)	4.45	8
Climate variability cause increase in invasive species of weeds affecting sugarcane	97(47.3)	104(50.7)	3(1.5)	1(0.5)	0(0.0)	4.45	8
Elevated temperatures increase disease infestation in sugarcane	96(46.8)	101(49.3)	7(3.4)	1(0.5)	0(0.0)	4.42	10
Climate variability makes sugarcane more vulnerable	98(47.8)	75(36.6)	28(13.7)	4(2.0)	0(0.0)	4.30	11

to insect and pathogens attacks							
Environmental stress caused by climate variability makes sugarcane less competitive with weeds	94(45.9)	79(38.5)	31(15.1)	1(0.5)	0(0.0)	4.30	11

Source: Field Survey, 2023.

4.4 Results and discussion on the knowledge of smallholder sugarcane farmers regarding climate variability adaptive strategies.

4.4.1 Smallholder farmers distribution regarding source of information on climate variability?

Table 7 result revealed that all (100%) the sugarcane farmers knew about climate variability information from farmer-to-farmer support/engagements meetings, which was their reliable source of information. This indicate that farmers in the area are aware of the advantages of information sharing and networking among one-another and they are ready to keep leveraging on this platform to reduce their vulnerability. According to Oduniyi, Ojo, and Nyam (2022), most sugarcane farmers in Nkomazi municipality are members of cooperative societies and farmers groups because they recognize the benefit of such platforms as a means of social networking, and collaborative effort, and information sharing on various innovative practices. Equally (100%) of smallholder sugarcane farmers indicated their most preferred and reliable source of information was during extension and advisory visits. Furthermore, Msuya et al. (2017) stated that agricultural extension has multiple goals, including transferring knowledge from global, national, and local researchers to farmers, helping them clarify their own goals and assessing their opportunities, educating them about decision-making processes, and promoting desirable agricultural development. Extension officers play a significant role in delivering information and agricultural extension is the primary delivery system for information to farmers in South Africa (Antwi-Agyei & Stringer, 2021).

Moreover, more than half (58%) of the sugarcane farmers knew about climate variability from the radio. These findings are consistent with the findings of Ubisi et al., (2017) who reported that radio is the main source of climate information for smallholder farmers in Limpopo. Lyamchai et al. (2011) concluded that 75% of Lushoto respondents accessed climate information through radio. Other sources of information presented to farmers were less preferred as their percentages were below (42%) and did not yield the desired results compared to those preferred by most farmers. (41.5%) of smallholder sugarcane farmers used television as their source of information in understanding climate variability phenomenon. Likewise, (16.1%) of farmers used internet to search for information regarding climate variability effects, and only (17.1%) knew about climate variability and its effects from family members, as their reliable source of information (on their own indigenous knowledge) and by observation of the weather system to improve their knowledge on climate variability.

Table 7: Frequency distribution of the respondents according to their most reliable source of information regarding climate variability.

Climate variability training	Frequency	%
Extension officers	205	100
Farmer to farmer	205	100
Radio	119	58
TV	85	45.5
Family members	35	17.1
Internet	33	16.1

Source: Field Survey, 2023.

4.4.2 Distribution of farmers based on their participation climate variability related training.

Table 8 results revealed that majority (84%) of smallholder sugarcane farmers never participated in any form of climate variability related training, whereas only (16%) of study participant participated in some degree of training. Also, the results in table 8 show that smallholder sugarcane farmers lacked training and information regarding climate variability. Moreover, it revealed the ineffectiveness of extension services regarding this area. This is consistent with the findings of Antwi et al., (2017), who reported that lack of information about climate variability, inadequate resources, and inadequate agricultural extension services contribute to the problems faced by smallholder farmers in South Africa. Therefore, training enhanced farmer awareness, knowledge, and skills, thus facilitating crop rotation adoption (Macharia et al., 2014; Musafiri et al., 2020b).

In addition, Nyairo et al. (2021) pointed out that understaffed extension and advisory service agencies are unable to disseminate education that improves smallholder farmers livelihoods. Most African countries' agricultural extension agencies are significant sources of knowledge and information for farmers in relation to innovative technologies (Kolleh, 2016). Besides, Agricultural extension and rural advisory services are a major channel whereby smallholder sugarcane farmers should access vital information and education on several innovative farming practices and strategies regarding climate variability. According to Mubirigi (2016), smallholder farmers cannot take advantage of opportunities to develop action programs that facilitate sustainable and desired changes due to a lack of education and training. Furthermore, Antwi-Agyei & Stringer, (2021) confirm that extension officers play a significant role in delivering information, with agricultural extension as the primary source of information for farmers. Consequently, there is a substantial knowledge gap hindering the flow of information about climate variability and adaptation. Thus, there is an urgent need to fill the gap in information flow between extension officers and smallholder sugarcane farmers in the study area. To provide more effective rural advisory services to farmers, public and private extension organizations must strengthen their ties with community-based organizations. These organizations include agricultural cooperatives. In this way, they can improve farmers' productivity and income by providing technical assistance. Rural communities can also benefit from such links and synergies by creating local employment opportunities.

Table 8: Frequency distribution of the respondents according to their participation in any form of climate variability related training

Climate variability training	Frequency	%
Yes	33	16.1
No	172	83.9

Source: Field Survey, 2023.

4.4.3 Smallholder sugarcane farmers knowledge level regarding climate variability.

Table 9 reveal that, out of the 16 knowledge level statements administered to smallholder sugarcane farmers regarding climate variability, and adaptive strategies available to mitigate this effect in the Nkomazi areas. A series of statements about the probable knowledge of climate variability adaptive strategies was presented to them, and their responses to these statements were captured as Yes, No and Not sure. From a list of 16 knowledge test statement rated on correct (1) and incorrect (0) scale. The results revealed that most smallholder sugarcane farmers were observing and experiencing changes. Among these changes are decreased rainfall, early rain cessation, warming temperatures, droughts, and shorter growing seasons. Results showed that they do not have a good understanding of climate variability. A smallholder sugarcane farmer was given 16 knowledge statements about climate variability and adaptive strategies, but half of them were correctly answered. The results indicate that participants had moderate knowledge levels. However, farmers lacked a comprehensive understanding of climate variability despite the study's encouraging results. Therefore, farmers need a better understanding of climate variability and adaptation strategies. The agricultural extension officers should provide them with the knowledge and skills they need to better manage climate variability.

Prominent statements where they were highly knowledgeable are: (1) what causes climate variability (100%); (2) Climate variability is caused by greenhouse gas emissions (100%); (3) Building water harvesting scheme can reduce the stress of unavailable water during intense drought conditions (100%), (4) Changing dates of planting and methods can lessen the effects of climate variability on sugarcane (100%); (5) Reduction in sugarcane thrash burning can help climate variability effects (100%), (6) the use of irrigation to supplement natural rainfall helps to increase sugarcane production (100%); (7) using sugarcane residue from past production (Mulching) can be used to suppress weed growth and improve soil structure and organic matter content on sugarcane farms (100%), and (8) Sugarcane trash can be used to control water and wind erosion that occurs because of climate variability (100%).

Moreover, this finding is also supported by the qualitative study. During the interview key informants showed immense knowledge regarding the effects of climate variability but exhibited limited knowledge regarding adaptive strategies available to them in the study area. The participants however, had some ideas on some adaptation strategies they can exploit. "One of the key informants stated that, they were advised to leave sugarcane residues on the field after harvesting as an adaptive strategy to protect the *soil against erosion during heavy rainfall also to avoid water stress and ensure optimum irrigation." Moreover, "another key informant indicated that during extension and advisory visits they had been advised to irrigate and apply manure to resolve nutrient deficiency as an adaptation strategy of cope with these effects without understanding or being trained".*

Schonbeck (2015) found that mulching is an effective way to control weeds in organic crops because it reduces weed seed germination, blocks the growth of weeds, and maintains soil moisture and temperature until the crop is established. The results further, indicates that extension agents in the study area might not be providing sufficient information to the smallholder sugarcane farmers given their moderate knowledge level regarding climate variability and adaptive strategies. The mission of the extension personnel is to provide research-based information focused on the needs of farmers. The findings of this study agree with Mango et al. (2017), that, extension officers are responsible for ensuring that farmers receive adequate access to relevant, timely, and appropriate information that will improve their productivity, livelihoods, maintaining competitiveness in the market and maximize profits for farmers, this is essential. Furthermore, extension officers should provide farmers with technical assistance and advice to assist them in resolving any issues they may be experiencing. Moreover, FAO (2016) also believes their participation will increase farmers' access to climate-resilient technology and activities and help improve smallholder farmers' productivity.

Table 9: Respondents knowledge level on climate variability.

Knowledge statements:	Correct	Incorrect
Climate variability is caused by angry nature.	205 (100)	0 (0.0)
Climate variability is caused by greenhouse gas emissions.	205 (100)	0 (0.0)
Reduction in bush and crop waste burning can reduce the cause of climate variability	67 (32.7)	138 (67.3)
Changes in timing of land preparation practices can help to reduce stress caused to sugarcane by climate variability.	49 (23.9)	156 (76.1)
Climate variability cannot be mitigated using drought resistant crop varieties.	52 (25.4)	153 (74.6)
Planting of cover crops reduces the effect of climate variability thereby protecting the soil from losing it nutrients.	43 (21.0)	162 (79.0)
Crop diversification cannot be used to reduce the effects of climate variability.	41 (20.0)	164 (80.0)
Using of stress tolerant and drought resistance cultivars can mitigate the effects of climate variability	42 (20.5)	163 (79.5)
KS9=Exogenous application of protectant such as phytohormones can have beneficial effects on sugarcane and alleviate the effects of climate variability	47 (22.9)	158 (77.1)
Building water harvesting scheme can reduce the stress of unavailable water during intense drought conditions.	205 (100)	0 (0.0)
Changing dates of planting and methods can lessen the effects of climate variability on sugarcane.	205 (100)	0 (0.0)
Reduction in sugarcane thrash burning can help climate variability effects	205 (100)	0 (0.0)
Use of irrigation to supplement natural rainfall helps to increase sugarcane production.	205 (100)	0 (0.0)

Sugarcane residue from past production can be used to suppress weed growth and improve soil structure and organic matter content on sugarcane farms.	205 (100)	0 (0.0)
Using mulching on sugarcane farming improve water use efficiency by preventing evaporation of moisture.	60 (29.3)	145 (70.7)
Sugarcane trash can be used to control water and wind erosion that occurs because of climate variability	205 (100)	0 (0.0)

Source: Field survey, 2023.

4.4.4 Respondents indigenous knowledge regarding climate variability and adaptive strategies.

Table 10 results revealed that all (100%) of smallholder sugarcane farmers rely on their indigenous knowledge regarding climate variability and adaptive strategies. Indigenous knowledge is generally transmitted from generation to generation through casual conversation, field practices, and fieldwork (Govender et al., 2013). Farmers tend to rely on indigenous knowledge passed down to them in the absence of extension services. Yet Goddard et al., (2010) suggest that Indigenous knowledge is in danger due to the absence of documentation in the context of weather and climate. Also, Noyoo (2007) and Kolawole et al., (2014) stressed the importance of documenting Indigenous knowledge as most of the older generation who hold Indigenous knowledge die with the information without passing it down. Therefore, if we do not find a way to capture their science and make it available, we will lose knowledge. An old African proverb states, "When an old knowledge person dies, a library is lost". The importance of documenting and making available IK information for future generations cannot be overstated. The survival of cultural heritage depends on its preservation and transmission.

Table 10: Respondents indigenous knowledge regarding climate variability and adaptive strategies?

Indigenous knowledge	Frequency	%
Yes	205	100
No	0.0	0.0

Source: Field Survey, 2023.

4.4.5 Indigenous indicators regarding climate used among smallholder sugarcane farmers.

Table 11 reveals historically utilised indigenous indicators regarding climate amongst smallholder sugarcane farmers in Nkomazi Local Municipality. Several indigenous indicators for weather and climate prediction based on cultural and environmental beliefs of study participants were captured. From the thematic analysis, most common indicators used by Nkomazi farmers to predict weather and climate were categorised into four groups: (i) clouds indicator's; (ii) high temperature indicators; (iii) fog in the early morning/atmospheric indicators (iv) the moon shape as an indicator. As a result of these indicators, farmers were able to make farm-level decisions and forecast weather, such as planting time and planning irrigation schedules, applying weeds and herbicides, applying pesticides and disease chemicals, and harvesting crops. The results reveals that all (100%) of the smallholder sugarcane farmers observed the changing of clouds to a darkish in colour which indicate or a signal for heavy rain coming in few hours. This finding is in line with Netshiukhwi et al. (2013) observation that dark clouds are well-known as indicators of heavy rains.

However, on the other hand 100% of sugarcane farmers reported that, primarily early morning high temperatures indicate good rain, and high temperature between September and October also indicated good rains. Moreover, all (100%) of farmers also reported that early morning fog is another indicator of heavy rains coming. A strong easterly wind in August indicates a good season ahead, whereas weak winds indicate a dry season. This observation helped in preparing the land for the upcoming summer season. Risiro et al. (2012) also found this to be true. However, since the tables have turned, smallholder sugarcane farmers now endure prolonged cold seasons into October due to prolonged dry seasons. The lower the summer rains, the warmer the winter will be, while high summer rains will indicate the colder the winter will be. The general belief among farmers was that high summer rainfall caused cold winters, and vice versa. In contrast to these observations, Charles et al. (2014) had different observations regarding rainfall variations as reported by farmers.

In addition, 20.5% of sugarcane farmers observed moon shapes that indicated the following: 1) Half-moons facing east indicate that there will be no rain, 2) Downward crescent shapes indicate that there will be heavy rain within the next few days, 3) Moons with haloes indicate continuous rains within two weeks, 4) bright moons signal the approaching winter seasons, while full moons indicate drought and dry spells. Based on the moon's appearance in the sky, smallholder sugarcane farmers could predict seasons. The moon undergoes several changes in shape, size, and colour over the course of its lifetime, according to the respondents. In this way, they can predict seasons based on the appearance of the moon. A half-moon facing east indicate that there will be no rain, whereas downward crescents indicate that heavy rain will occur. Furthermore, smallholder sugarcane farmers explained that a moon with a halo signalled good and continuous rains within approximately two weeks. These findings contrast with those of Charles et al. (2014), since farmers have reported differing observations regarding rainfall variability. Moreover, Mpandeli, Nesamvuni, and Maponya (2015) and Jiri et al. (2016) performed a similar study in South Africa and reported that star movement from west to east at night under clear skies signals the coming of rain. A similar observation was made by Mapara (2009) that some Indigenous climate indicators are specific to geographical areas. While rural farmers face great challenges due to climate variability, they are still able to adapt and cope by using indigenous knowledge indicators. Indigenous knowledge is used by farmers to forecast the weather and determine when to plant crops.

Table 11: Distribution of respondents by indigenous climate indicators used.

Climate indicators used	Frequency	%
Clouds	205	100
High Temperature/Fog in the early morning	205	100
Moon	42	20.5

Source: Field Survey, 2023.

4.4.6 The utilization of Indigenous climate knowledge regarding climate variability.

Table 12 reveals that a great number (100%) of smallholder sugarcane farmers in Nkomazi municipality areas, in Southern Africa are using their indigenous climate indicators for weather predictions to make critical short-term decisions for their farming practices and adaptive measures. This finding is in line with studies conducted by Jiri, Mafongoya, and Chivenge (2015) and Rankoana, (2016) that smallholder farmers have developed indigenous skills that have enabled them to cope with long droughts and severe heat conditions despite climatic variability. In addition, in some areas, smallholder farmers depend exclusively on indigenous knowledge to determine harvesting and planting seasons based on climate indicators (Ubisi et al., 2017). As a result, they were able to adapt their farming practices to the changing climate. It is also important to note that this approach minimized the use of chemicals and external inputs, thereby conserving natural resources. This approach also helps to maintain traditional agricultural practices, which are beneficial to the environment and rural communities. Furthermore, it ensures that smallholder farmers remain resilient to climate variability.

Table 12: Frequency distribution according to the utilization of indigenous climate knowledge.

The utilization of indigenous climate knowledge	Frequency	%
Yes	205	100
No	0.0	0.0

Source: Field Survey, 2023.

4.4.7 Means used to acquire indigenous knowledge climate indicator.

Table 13 reveals that (100%) of smallholder sugarcane farmers in Nkomazi municipality areas acquire their indigenous knowledge from personal experience, and (99.5%) of farmer noted that their indigenous knowledge was passed down to them. These findings agree with research that was conducted by Govender et al., (2013), Indigenous knowledge is passed from generation to generation by elderly people through fieldwork and casual conversation since they are responsible for preserving indigenous knowledge. Indigenous communities use this knowledge every day in order to manage natural resources, make decisions, and resolve issues. Knowledge derived from Indigenous cultures is crucial to the survival of those cultures, and therefore, it should be respected and preserved.

Table 13: Means used to acquire indigenous knowledge Climate indicator

Means to acquire indigenous knowledge	Frequency	(%)
Passed down	205	100
Personal experience	205	100
Formal education	0.0	0.0

Source: Field Survey, 2023.

4.5 Results and Discussion on the Adaptation Strategies utilized in the study areas.

4.5.1 Adaptive strategies utilization level among smallholder sugarcane farmers.

Respondents were asked to indicate the strategies they use on a 3-point utilization scale of highly utilised (3), moderately utilized (2), and not utilized (1). The actual mean is 2 based on the rating scale used and a mean of greater than 2 signifies a high level of utilization while a mean below 2 is deemed a low level of utilization by the farmers. The results in Table 14 reveals that most of the adaptive strategies presented to the participants were not utilized by these farmers due to certain constraints and challenges hence it showed a low level of utilization of this adaptation strategies. Using mean scores to rank the utilized climate adaptation strategies according to their order of use, the results showed only two prominent strategies used by the smallholder sugarcane farmers, which was the efficient use of irrigation systems AD1(MS=3.00), and the use of manuring on sugarcane farm AD4(MS=3.00) as they all ranked 1st, 2nd. This finding agrees with Mpandeli and Maponya (2014), who discovered that the smallholder farmers in South Africa were faced with serious constraints and challenges.

Key informant, "response stated their preference for drip irrigation system over sprinkler because of its 95% water efficiency". Furthermore, "participants indicated that, they received information regarding climate variability adaptive strategies but were unable to adopt because they are expensive to implement, and their land size is another factor". "It is understood that crop rotation is an important farming practice that has the potential to improve the quality and fertility of the soil. Nevertheless, it has been emphasized that more land is required to enable crop rotation."

With further investigation about farmers inability to utilize these available adaptive strategies, we discovered a series of constraints which these farmers professed e.g. the lack of extension officials/services who are knowledgeable about climate variability issues and adaptive strategies, inadequate access to drought, pest/disease resistance cultivars, good quality and vigorous seeds such as hybrids and open-pollinated varieties. Moreover, these farmers are unable to utilize the available adaptive strategies in the study area, due to poor access to information, lack of training, workshops regarding climate variability.

The findings agree with Antwi et al., (2017), who reported that lack of information about climate variability, lack of sufficient resources, and inadequate agricultural extension services are major challenges faced by smallholder farmers in South Africa. This implies that there is no proper training and transfer of skills to smallholder sugarcane farmers from extension agencies and rural advisors in the area. There is a significant knowledge gap that exist between extension officials and smallholder sugarcane farmers that, requires government and other stakeholders' attention to improve this grey area concerning climate variability adaptation strategies. Stoutenborough and Vedlitz (2013) highlighted the importance of information as a key enabler of innovation adoption and utilization.

Table 14: Frequency distribution according to the study respondents regarding their level of utilization of adaptive strategies

Strategies	**Not Used**	**Moderately used**	**Highly used**	**Mean score**	**Ranks**
Efficient use of irrigation systems	0(0.0)	0(0.0)	205(0.0)	3.00	1
Use of manuring on sugarcane farm	0(0.0)	0(0.0)	205(100)	3.00	1
Changes in harvesting and planting dates	141(68.8)	0(0.0)	64(31.2)	1.62	2
Drought resistant sugarcane varieties	171(83.4)	2(1.0)	32(15.6)	1.32	3
Finding off-farm jobs	174(84.9)	0(0.0)	31(15.1)	1.30	4
The use of chemical fertilizer	204(99.5)	0(0.0)	1(0.5)	1.01	5
Practicing crop diversification	205(100)	0(0.0)	0(0.0)	1.00	6

Building water harvest scheme	205(100)	0(0.0)	0(0.0)	1.00	6
Mixed cropping	205(100)	0(0.0)	0(0.0)	1.00	6
Improve in water maximization.	205(100)	0(0.0)	0(0.0)	1.00	6

Source: Field survey, 2023

4.5.2 Respondents support services received to sustain these adaptive strategies.

The result in Table 15 shows that (74.1%) of smallholder sugarcane farmers received less support from government or private sectors regarding the above-mentioned adaptation strategies. Furthermore, (24.4%) of farmers received adequate support, and 1.5% of farmers received very less support. The inadequacy of agricultural extension services and support regarding climate variability adaptive strategies from both governmental and private agencies these farmers, stive in finding vital information to improve and sustain the livelihoods of members through their farmer groups and cooperative societies. The findings of this study are in agreement with those of Sinyolo and Mudhara (2018), stating that cooperatives provide a variety of services to their members. Among these services are disseminating market information, providing inputs and labour, facilitating credit and saving, and providing training opportunities. Additionally, cooperatives also provide access to inputs and credit, as well as access to skills and knowledge. They also provide a platform for members to voice their concerns and advocate for better policies. Oduniyi, Ojo, and Nyam (2022) confirm that most farmers in Mpumalanga belong to cooperative societies and farmers' groups. Since they are aware of the merits of such platforms as a medium for social networking, collaborative work, and information exchange on various innovative practices, they are willing to invest in such platforms. This highlights the importance of these organizations for the growth and success of farming in the region. Furthermore, these organizations can provide farmers with access to resources and support, enabling them to improve their livelihoods.

Table 15: Support received to sustain need to sustain adaptation practices.

Support	Frequency	(%)
Very less support	3	1.5
Less support	152	74.1
Adequate support	50	24.4

4.5.4 Support needed regarding climate variations.

The result in Table 16 shows the significant support gap that exist between smallholder sugarcane farmers and extension services regarding adaptive strategies in the study area. The results reveal that (100%) of farmer marked all five options on the questionnaire administered as their needs. Furthermost (100%) of sugarcane farmers requested farm management technical support, 99% of farmers requested to be trained on natural disaster awareness and other risk reduction management practices and another (99.5%) of farmers continued to request financial support. In addition, 97.1% of farmers also requested to be educated and trained on climate variability effects and the application of adaptive strategies. Moreover, (100%) of sugarcane farmers requested training on improved and resilient farming practices available. These finding shows a prodigious need for government and other stakeholders to improve their support service and dissemination/ transfer of information to smallholder sugarcane farmers addressing their felt needs.

This finding is also supported by the qualitative aspect of the study. "Key informants results revealed that there is lack of support from the government. As a result, the farmers have also pleaded for the government to assist them with water pumps to achieve optimum irrigation". Key informant further revealed that, "they are experiencing several infrastructural related challenges including outdated and unmaintained existing water pumps, high transport and labor costs, loadshedding, theft of electricity cables, lack of climate variability information, training on climate adoption and application strategies, innovative sugarcane management practices and irrigation sprinklers."

Furthermore, Stoutenborough and Vedlitz (2013) emphasized the importance of information in enabling innovation adoption and application. The results of this study indicate that extension agencies and rural advisors in the area are not adequately training and transferring skills to smallholder sugarcane farmers. Governments and other stakeholders are responsible for providing technical assistance. This process will provide farmers with timely and accurate information about the latest technologies, as well as financing and technical assistance.

Moreover, the government should also provide incentives for smallholder farmers to adopt and use new technologies, as well as other services that will assist extension officers and organizations to provide more effective education/training, as well as rural advisory services on ever-changing agricultural fraternity and climate variability adaptation strategies that meet the needs of smallholder sugarcane farmers in the study area. Smallholder farmers are unable to take advantage of opportunities to develop action programs that will facilitate the desired and sustainable transformation of their communities due to a lack of support, education, and training. Mubirigi (2016) points out that despite the lack of farmer support, education, and training, smallholder farmers cannot take advantage of these opportunities. In South Africa, Sinyolo and Mudhara (2018) recommend that the government and development agencies recognize and emphasize the importance of collective actions through groups. The purpose of this program is to provide inputs and other support services to smallholder farmers.

Table 16: Support needed regarding climate variations.

Needed Support	Frequency	(%)
Farm management technical support	205	100
Education on resilient farming practices	205	100
Financial support	204	99.5
Risk reduction support	203	99
Education on climate variability	199	97.1

Source: Field Survey, 2023

4.6 Chapters Summary.

This chapter provided an overview of the findings and discussion of the descriptive analysis of the socio-economic characteristics of the smallholder sugarcane farmers, the perceived effects of climate variability on sugarcane production, the knowledge of smallholder sugarcane farmers regarding climate variability and adaptive strategies utilized in the study areas. The findings of the socioeconomic characteristics revealed that three-quarters 74% of smallholder sugarcane farmers were aged from 50 years and above and had a mean age of 58.03 years, and more than half of the smallholder sugarcane farmers were males 54 %, married 67 %. The finding revealed that 81% of the respondents had a family size ≤ 5 and above persons, The mean family size found among the smallholder sugarcane farmers in the area is 7 persons with a standard deviation of 3 persons. The study findings further revealed that majority of smallholder sugarcane farmers had farming experience accounting 10 years and above with ownership of land (farm size) more than five hectares. Furthermore, the findings reveal that 45% of the smallholder sugarcane farmers had attained a secondary educational level. Moreover, the findings indicated that, majority 85% of smallholder sugarcane farmers had secondary occupations, which mean majority of sugarcane farmers have also diversified into non-farm livelihood activities to ensure sustainable livelihoods. The results showed that smallholder sugarcane farmers had secondary occupation that they dependent on to supplement their farming activities. It's evident that the farmers needed strategies to cope with the farming challenges exacerbated by climate variability. Despite the climatic variability, findings showed that sugarcane farmers strived for higher production output with substantial differences in annual productivity observed in 2020 and 2022. The observed difference in productivity demonstrated a significant decline of 1.5% in two consecutive growing seasons. In this regard, smallholder sugarcane farmer's productivity must be enhanced by adapting to climate-related strategies. Regarding the perception of smallholder sugarcane farmers on the effects of climate variability the findings of the study showed that they had a very high perception level. The change in temperature, soil degradation and erosion, increased temperature, decreases sugarcane production, intense drought conditions negatively affect sugarcane production and yield respectively. The result revealed that all the sugarcane farmers knew about climate variability information from farmer-to-farmer support/engagements meetings, which was their reliable source of information. The benefit of such platforms as a means of social networking, and collaborative effort, and information sharing on various innovative practices. Equally all the smallholder sugarcane farmers mostly preferred extension and advisory visits to source reliable information while other channels were also used as alternative source of information on climate variability. The remaining source of information presented to the farmers were less preferred as their percentage where below 42% and where not substantially used. However, majority (100%) of the smallholder sugarcane farmers never participated in any form of climate variability related training, and this resulted to poor understanding of climate variability adaptive strategies amongst the farmers. In this regard, it could be deduced that the extension services in this area were ineffective.

About the knowledge level statements administered to participants, the results revealed that most smallholder sugarcane farmers correctly answered half (8) out of the 16 knowledge statements administered to them. The results indicate that the study participants had a moderate level of knowledge regarding the effect of climate variability. The results indicate that smallholder sugarcane farmers lack a comprehensive understanding on the effects of climate variability. The results further revealed that most of the adaptive strategies presented to participants were not utilized by the smallholder sugarcane farmers. The results implied that smallholder sugarcane farmers are unable to effectively and optimally utilize adaptive strategies due to severe constraints faced. These constraints include “poor access to timely and updated information and knowledge on climate variability”, “lack of training on the use of adaptation strategies”, “inadequate access to extension services”, “unpredictable rainfall”, “Inadequate access to credit facilities and support”, and “Inadequate access to resistant seed varieties” among others.

CHAPTER FIVE
FINDINGS AND DISCUSSION ON INFERENTIAL ANALYSIS

5.1 Chapter Introduction

The chapter gives the findings and discussion on the inferential analysis of the study used to relate key variables in the study together and draw appropriate inferences. The following hypotheses stated in the null form were statistically tested in the study. The first was to statistically test is there was no significant difference in the smallholder sugarcane farmers production output across two (2) growing seasons. A paired t-Test analysis was used for this analysis. Moreover, the second research hypothesis was to statistically test whether the smallholder sugarcane farmers socio-economic characteristics does not influence their utilization of adaptation strategies. This was also achieved using multiple linear regression analysis.

5.2 T-test Analysis of change on smallholder sugarcane farmer's production output for 2020 - 2022 growing Seasons.

Table 17 below presents comparison of smallholder sugarcane farmers production output from 2020 to 2022 growing seasons. According to the results, there was a statistically significant difference ($t = 3.970$; $P = 0.001$) found between the smallholder sugarcane farmers' production output in 2020 growing season ($M = 603.00$, $SD = 198.869$) and production output in 2022 growing season was ($M = 571.928$, $SD = 197.4267$). This implies that smallholder sugarcane farmers experienced a significant decline in their production output in the year 2022 growing seasons. This finding is in line with RCL Foods (2018) who reported a drastic decline e in the sugarcane production among smallholder farmers in Nkomazi local municipality. Also, Metiso and Tsvakirai (2019) confirm that smallholder sugarcane farmers, especially in the Mpumalanga province continue to experience production decline. This, therefore, indicate the need for smallholder sugarcane farmers to adapt and utilise the existing adaptation strategies to reduce their vulnerability and adequately be able to sustainable cope with the effects associated with climate variations in the study areas.

Table 17: Paired Sample T-Test for change in smallholder sugarcane farmers production output for 2020 and 2022 growing seasons.

Growing Seasons		Mean	Std.dev	N	T	Df	Sig
Change in Output	2020 Season	603.00	198.869	205	3.970	204	0.001
	2022 Season	571.928	197.4267	205			

Significance tested at 0.001 level.
Source: Analysis of Field Survey data, 2023.

5.3 Sugarcane farmers socio-economic factors influencing their utilization of climate variability adaptation strategies.

This section discusses the findings as to whether smallholder sugarcane farmer's socio-economic characteristics significantly influence their utilization of climate variability adaptation strategies. The result of the multiple linear regression analysis as shown in Table 18 reveals that the F-value (69.140) for the model was statistically significant at $P < 0.01$ with an R Square-value of 0.738. The test for multicollinearity between the variables was carried out using the Variance Inflation Factor (VIF) test and a mean value of 1.39 indicated that multicollinearity was not an issue coupled with the fact that most of the variables also had a high tolerance value.

The analysis further revealed that four out of the variables fitted into the model were statistically significant socio-economic factors influencing the smallholder sugarcane farmers' utilization of climate variability adaptation strategies in the area. These variables were secondary occupation (t=22.380) which was significant at a 1% percent level of significance, farming experience (t=2.223) was significant at a 5 % percent level of significance, Age (t=-1.724), and Family size (t=-1.675), which were both statistically significant socio-economic factors at a 10 percent level of significance. The coefficient of the two variables (secondary occupation, farming experience) had a positive relationship and coefficient of the other two variable (age, family size) had a negative relationship with the smallholder sugarcane farmers' probability of using climate variability adaptation strategies in the study area, hence the second null research hypothesis postulated for the study was rejected.

The coefficient of secondary occupation ($B=4.814$; $P<0.001$) of smallholder sugarcane farmers had a positive and significant influence on their use of climate variability adaptation strategies. The results show that with one unit increase in the secondary occupation smallholder sugarcane farmers translate to statistically significant increase in the utilization of climate variability adaptation strategies. This implies that most of the smallholder farmers in the area do not rely just on the income generated from sugarcane production for survival, as they also diversify into non-farm livelihood activities to generate extra income to ensure a sustainable livelihood. Moreover, farmers who diversify from sugarcane farming to other off-farm livelihood strategies increases the probability of farmers adopting and using climate variability adaptation strategies. This is in line with Mzuyanda, (2014) asserting that, non-farm jobs are essential to diversify income sources and improve the livelihoods of members. Balana et al. (2021) also confirms that, involving and encouraging smallholder farmers in livelihood diversification strategies would reduce their vulnerability to food insecurity, and poverty in case of their exposure to climate risk and shocks which negatively affect their farm enterprise as this will guarantee their livelihood sustainability.

The coefficient of farming experience ($B.024$; $P<0.027$) indicated a positive and statistically significant in the model. This translates to significant increase in the utilization of climate variability adaptation strategies by farmers with more years of farming experience compared to those with few years in farming experience. This shows that the more years spent on farming influences the adoption of an adaptation strategy. This result agrees with the findings of Alhassan et al. (2019) and Mwungu et al. (2018), who found that farmers increase their resilience in response to environmental changes by employing adaptation measures. Moreover, this indicates that smallholder farmers who have been into sugarcane production over years must have accumulated experienced and has perceived the effects of climate variability over time. This will most likely influence their decision to adopt and utilize climate variability adaptation strategies as a form of sustainable land management practices against climatic effect. Farmers experience has a direct influence on their level of innovation adoption of adaptation strategies. Aminu et al. (2018), Mugisha and Alobo (2012), and Motavali and Bardhan (2013) concluded that having a substantial level of experience always enables smallholder farmers to devise strategies to deal with land degradation problems. This is done through different land management practices. Furthermore, Barongo (2021) states that new farmers develop a better understanding of the environment, as well as the changing aspects of climate variability, which then enhances their ability to solve problems. The result is more sustainable farming practices and better decision-making, and agricultural success is more likely to last.

The coefficient of the smallholder sugarcane farmer's Age (B -0.014; $p<0.086$) was negative and statistically significant ($p<0.10$) in the model. This indicates a negative and significant influence on smallholder sugarcane farmers utilization of climate variability adaptation strategies. Hence, the negative sign might be ascribed to the fact that older people may be more cautious and resistance to change, fixed income or reduced financial resource can hinder investment in adaptive measures being implemented. Moreover, older farmers have high health issues or mobility constrains which can restrict participation in adaptive activities-training as well as lack of familiarity with technology. This result agrees with Obasi et al. (2013), an aging farmer's population can have a significant negative impact on the efficiency and sustainability of agricultural production and the adoption of innovative strategies. Hence, there is a need to encourage increased participation of the younger generation in farming enterprises to secure the future of agriculture and ensure food security in the area.

Furthermore, the coefficient of family size (B -0.042; $p<0.096$) showed a negatively and statistically significant ($p<0.10$) in the model. This means that a larger family size is less likely to decrease the probability of farmers utilization of adaptation strategies as compared to farmers with small family size. This could be attributed to the fact that larger family size has more mouth to feed within limited resources, leading to them to struggle to allocate funds for adaptive measure such as climate-resilient cultivar. Moreover, their increased childcare responsibility having less time to devote to adaptive strategies activities, such as planning, learning or implementing these practices decreases the probability to adopt and use these adaptive strategies. In contrary Marenya and Barrett (2007) found that larger family sizes were an asset in agricultural activities since they provided labour for farming. Further, Olorunfemi et al. (2014) attests that family size is generally linked to labour sources, with many farmers who have large households typically finding their family members helpful.

Table 18: Socio-economic factors influencing smallholder sugarcane farmer's utilization of climate variability adaptation strategies.

Variables	Coeff.	Std Err	T	p>t	Sig	VIF	Tolerance
Gender	.096	.153	.024	.629	.530	1.055	.948
Age	-.014	.008	-.093	-1.724	.086***	2.198	.455
Marital status	.022	.196	.005	.112	.911	1.545	.647
Family size	-.042	.025	-.065	-1.675	.096***	1.119	.894
Educational level	-.060	.075	-.037	-.794	.428	1.610	.621
Secondary occupation	4.814	.215	.849	22.380	.001**	1.079	.927
Years of farming experience	.024	.011	.098	2.223	.027*	1.452	.689
Farm size	-.001	.045	-.001	-.026	.979	1.073	.932
Mean VIF						1.39	
F	69.140						
Prob > F	<.001						
R–Squared	.738						

Note: Significance difference levels at *** 5%,** ** **at 1%,** and *** at **10%**

Source: Field Survey, 2023

5.4 Chapters Summary.

This chapter presented and discussed the inferential statistics used in the study which includes t-Test analysis and multiple linear regression. These analyses were used to statistically test the relationship between variables as postulated in the study hypotheses. A paired sample t-test was carried out to compare smallholder sugarcane farmers production output from 2020 to 2022 growing seasons. The analysis results revealed that there was a statistically significant difference between the smallholder sugarcane farmers' production output in 2020 growing season and in 2022 production output season. The observed difference in productivity demonstrated a significant decline of 1.5% in two consecutive growing seasons. This implies that smallholder sugarcane farmers experienced a significant decline in their production output in the year 2022 growing seasons. In this regard, smallholder sugarcane farmer's productivity must be enhanced by adapting to climate-related strategies. Furthermore, the multiple linear regression model showed that secondary occupation, farming experience, farmers age and family size were significant determinants of smallholder sugarcane farmers utilization of climate variability adaptation strategies.

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CHAPTER SIX
SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

6.1 Chapter Introduction

Climate variability and its effects on agriculture and human survival remain a global concern requiring continual research and the use of coping strategies. This study assesses the perceived effects of climate variability, and adaptive strategies utilized amongst smallholder sugarcane farmers in the Nkomazi area of South Africa. The study-specific objectives were to determine the perceived effects of climate variability influencing sugarcane production in the area; Examine smallholder sugarcane farmers knowledge on climate variability adaptive strategies; Ascertain adaptation strategies utilized by smallholder sugarcane farmers. This study adopted a mixed methods approach as a methodology of collecting, analyzing, and integrating quantitative and qualitative research in a single study to determine how smallholder sugarcane farmers in the local municipality of Nkomazi perceive the effects of climate variability and their use of adaptive strategies. This method was adopted with the intended to provide a better understanding of the research problem than either a quantitative or qualitative approach alone through the combination of both.

A two-staged sampling procedure was used to select two hundred and five (205) respondents for the study. The first stage was a purposive selection of smallholder sugarcane farmers producing on less than 10 hectares of land and supplying sugarcane to RCL foods (Nkomati mill) while the second stage was then a proportionate random selection of smallholder sugarcane farmers in the study. With the assistance of extension officers, the researcher and trained enumerators administered a structured questionnaire to elicit information from the farmers during interview sessions. Furthermore, a mixed method was used to collect data. The collected data for each objective were analyzed using descriptive statistics, t-Test analysis was used to compare smallholder sugarcane farmers production output from 2020 to 2022 growing seasons, and multiple linear regression was used to determine the socioeconomic factors influencing farmers' use of climate adaptation strategies.

6.2 Summary of major findings.

The findings of the socioeconomic characteristics revealed that three-quarters 74% of smallholder sugarcane farmers were aged from 50 years and above and had a mean age of 58.03 years, and more than half of the smallholder sugarcane farmers were males 54 %, married 67 %. The finding revealed that 81% of the respondents had a family size ≤ 5 and above persons, The mean household size found among the smallholder sugarcane farmers in the area is 7 persons with a standard deviation of 3 persons. The findings study revealed that majority of sugarcane farmers had farming experience accounting 10 years and above with ownership of land (farm size) more than five hectares. Furthermore, the findings reveal that 45% of the smallholder sugarcane farmers had attained a secondary educational level. Moreover, findings indicated that, majority 85% of smallholder sugarcane farmers had secondary occupations, which mean majority of sugarcane farmers have also diversified into non-farm livelihood activities to ensure sustainable livelihoods. The results showed that smallholder sugarcane farmers had secondary occupation that they dependent on to supplement their farming activities. It’s evident that the farmers needed strategies to cope with the farming challenges exacerbated by climate variability. Despite the climatic variability, findings showed that sugarcane farmers strived for higher production output with substantial differences in annual productivity observed in 2020 and 2022. The observed difference in productivity demonstrated a significant decline of 1.5% in two consecutive growing seasons. In this regard, smallholder sugarcane farmer's productivity must be enhanced by adapting to climate-related strategies. Regarding the perception of smallholder sugarcane farmers on the effects of climate variability the findings of the study showed that they had a very high perception level. The change in temperature, soil degradation and erosion, increased temperature, decreases sugarcane production, intense drought conditions negatively affect sugarcane production and yield respectively. The result revealed that all the sugarcane farmers knew about climate variability information from farmer-to-farmer support/engagements meetings, which was their reliable source of information. The benefit of such platforms as a means of social networking, and collaborative effort, and information sharing on various innovative practices. Equally all the smallholder sugarcane farmers mostly preferred extension and advisory visits to source reliable information while other channels were also used as alternative source of information on climate variability. The remaining source of information presented to the farmers were less preferred as their percentage where below 42% and where not significantly used. However, majority of smallholder sugarcane farmers never participated in any form of climate variability related training, and this resulted to poor understanding of climate variability adaptive strategies amongst the farmers. In this regard, it could be deduced that the extension services in this area were ineffective. About the knowledge level statements administered to participants, the results revealed that most smallholder sugarcane farmers correctly answered half (8) out of the 16 knowledge statements administered to them. The results indicate that the participants had a moderate knowledge level regarding the effect of climate variability. Moreover, t-Test analysis results revealed a significant difference in the 2020 output and 2022 growing seasons, which smallholder farmers largely experienced in significant decline in sugarcane production due to climate variability effect in the area during these growing seasons. Furthermore, the multiple linear regression model revealed that secondary occupation, and farming experience, farmers age and family size were significant determinants of smallholder sugarcane farmers' utilization of climate variability adaptation strategies in the study area.

6.3 Conclusion

This study concluded that most smallholder sugarcane farmers in Nkomazi municipality evidently perceived changes in the timing of seasons, climatic indicators during the decade preceding the survey and these variations are negatively affecting their sugarcane production and their livelihoods. The study revealed that from 2020 to 2022 the was a significant decline in sugarcane production. Smallholder sugarcane farmers experienced extreme weather events such continued drought and rainfall pattern inconsistencies of which negatively affected the growth and development of sugarcane, leading to loss of productivity drastically. Likewise, excessive rainfall led to land degradation causing the loss of topsoil and manure due to flooding. Temperature increases led to high pest and diseases infestation which severely reduce yield and coursed farmers to sell, others to lease their land. Though, smallholder sugarcane farmers have been experiencing some challenges in the past such as lack of timely and updated information and knowledge regarding climate variability, insufficient training on adaptation strategies, limited access to resources, finance, technology, and inaccessibility to extension services. Smallholder sugarcane farmers employed several coping strategies to cope with the perceived climate variability effects such as, using drought resistant sugarcane varieties, Efficient use of current available irrigation systems, finding off-farm jobs, applying fertilizer/manuring on sugarcane, changes in harvesting and planting dates, and expending their indigenous knowledge passed down them.

6.4 Recommendation

The following recommendations were made based on the findings of the study:

1. The government should establish adaptation funds and financing mechanisms to integrate adaptation into national and local policies. This will enable farmers to scale up adaptation strategies to enhance resilience and reduce vulnerability to the impacts of climate change and variability. Moreover, governments should invest in research and development so that farmers can better understand the changing climate and adapt accordingly. Finally, governments should create incentives to encourage farmers to adopt sustainable farming practices.

2. Improve the efficiency and effectiveness of institutions, for example through the strengthening of extension staff and the training of them on climate variability and adaptation strategies, as well as other conservation agricultural practices. The purpose of this is to ensure accurate and timely information is disseminated to farmers, which will facilitate better adaptation and enhance their well-being. As a result, farmers will have access to the latest information and technical advice, thereby enabling them to make informed decisions and become more resilient to the effects of climate change.

3. Government and other rural advisory stakeholders should focus more attention on the usage of the prominently preferred sources of information to archive anticipated capacity-building among sugarcane farmers in the study area.

4. To relieve the constraints, extension agencies should provide farmers with continuous climate variability-related training to ensure optimal usage of adaptation and mitigation strategies. Such training should include topics such as climate change,

best practices, and technologies. Extension agencies should also provide farmers with technical support and access to resources to help them implement these strategies. Finally, extension agencies should monitor and evaluate the effectiveness of these strategies.

5. Climate variability and change should be mainstreamed into food and nutrition security-related policies, plans, and programs, and the engagement of youths to overcome “the energy crisis” and literacy problem to access climate variability and change information should also be encouraged. Furthermore, the dissemination of climate-related information should be improved, including through the media, to ensure public understanding and engagement. Finally, the development of early warning systems must be accelerated to help communities prepare for and respond to climate-related disasters.

6. The government should set up adequate policies and facilitate strategies to provide accessible and affordable financial credit schemes. In addition, it should provide drought-resistant cultivars to ensure smallholder farmers have adequate access to them when needed and at subsidized rates in the area. This will help farmers to stay productive and productive in times of drought or other natural disasters. Furthermore, this will also help to reduce hunger and poverty in rural areas.

7. Climate variability must be addressed by the government by providing support for farmers especially by focusing on the significant determinates that were highlighted in the MLR analysis such as, secondary occupation, farming experience, farmers age and family size. Additionally, the government should provide incentives for farmers to switch to more sustainable agriculture practices, climate-smart agricultural farming, and other agroecological approaches (conservation agriculture).

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8. APPENDICES

APPENDIX 1: RESEARCH QUESTIONNAIRE

UNIVERSITY OF MPUMALANGA

UNIVERSITY OF MPUMALANGA

FACULTY OF AGRICUTURE AND NATURAL SCIENCES

SCHOOL OF AGRICULTURAL SCIENCES

RESEARCH QUESTIONNAIRE

TOPIC: PERCEIVED-EFFECTS OF CLIMATE VARIABILITY AND ADAPTIVE STRATEGIES UTILIZATION AMONG SMALLHOLDER SUGARCANE FARMERS IN NKOMAZI, SOUTH AFRICA.

Questionnaire serial no:	
Researcher's Name	
Student Number:	
Farm, village and / or co-operative name:	

This questionnaire is for the above stated study which is specifically for academic purpose. The research outcomes will provide information for academics, researchers, extension agencies and governments on how best to improve sugarcane farmers adaptability to climate variability. There are no anticipated risks or discomforts related to this research. All information obtained shall be treated with all the confidentiality it deserves and shall be used solely for the purposes of this study. Feel free to answer all the questions with as much truth as possible. Your participation in this study is voluntary and you have the right to withdraw at any stage without any penalty. Thank you for your anticipated participation and cooperation.

Researcher Participant consent

I hereby declare that I fully understand the purpose and nature of the research. All my questions have been answered satisfactorily and I agree and consent to voluntarily participate in this academic research study.

Respondent's Signature ……………………………… Date…………………...

SOCIO-ECONOMIC DEMOGRAPHICS OF SMALLHOLDER SUGARCANE FARMERS:

1. **Gender** Male ( ) Female ( )

2. **Age** ( ) **years**

3. **Marital Status of the household head**
   Married ( ) Unmarried ( )

4. **Family size:** *Please indicate the number of people in your household?*
   ( ) persons

5. **Level of education**
   What is your highest level of education that you have completed?

No school ( ) Primary ( ) Secondary ( ) Tertiary ( ) ABET ( )

6. **Secondary occupation:** *Are you engaging in any form of occupation aside from sugarcane farming?*
   Yes ( ) No ( )

7. **Years of farming experience in sugarcane farming: _______Years.**

8. **What is the total size of your sugarcane farm: _______Hectares.**

9. **Means of land ownership**
   Communal land ( ) Own land ( ) sub-leasing ( ) Rental/leased( )
   Other (specify)________________________

10. **What is your source of water for sugarcane irrigation?**
    Rain fed ( ) Dams ( ) Rivers ( ) Borehole( ) Harvested water ( )
    Others (please specify) ________________________________

11. **What is your estimated total sugarcane production output and income for the last 3 years?**

Year in production	Output in tons	Income Rands
2020		
2021		
2022		

12. **Do you belong to any farmer organisation?**
    Yes ( ) No ( )

13. **Do you receive any extension services?**
    Yes ( ) No ( )

PERCEPTIONS OF SMALLHOLDER SUGARCANE FARMERS REGARDING CLIMATE VARIABILITY FACTORS INFLUENCING SUGARCANE PRODUCTION.

Kindly indicate your perception on the potential resultant effects of climate variability factors on sugarcane production.

Statements	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Mean	Rank
14. Climate variability is responsible for the change in temperature.							
15. Climate variability can cause soil degradation and erosion							
16. Climate variability makes sugarcane more vulnerable to insect and pathogens attacks							
17. Environmental stress caused by climate variability makes sugarcane less competitive with weeds							
18. Climate variability is responsible for the unpredictable rainfall intensity							
19. The drying of river, dams and other water bodies are resultant effect of climate variability							

20. Water stress caused by climate variability reduces herbicides efficiency in sugarcane							
21. Increased temperature which results from climate variability decreases sugarcane production.							
22. Soil fertility on sugarcane farms is reduced by climate variability							
23. Intense drought conditions negatively affect sugarcane production and yield							
24. Elevated temperatures increase disease infestation in sugarcane							
25. Climate variability cause increase in invasive species of weeds affecting sugarcane							

KNOWLEDGE OF SMALLHOLDER SUGARCANE FARMERS REGARDING CLIMATE VARIABILITY ADAPTIVE STRATEGIES

26. What is your most reliable source of information regarding climate variability?
Radio ( ) Internet ( ) Tv( ) Farmer to farmer( ) Family members( )
Extension officers( ) Others (please specify) ________________________

27. Have you participated in any form of climate variability related training?
Yes ( ) No ( )

Kindly indicate your knowledge on climate variability adaptive strategies.
What is your knowledge level on climate variability regarding the following:

Knowledge statements:	**Yes Correct**	**Not Correc**	**Not sure**
28. Climate variability is caused by angry nature.			
29. Climate variability is caused by greenhouse gas emissions.			
30. Reduction in bush and crop waste burning can reduce the cause of climate variability			
31. Changes in timing of land preparation practices can help to reduce stress caused to sugarcane by climate variability.			
32. Climate variability cannot be mitigated using drought resistant crop varieties.			
33. Planting of cover crops reduces the effect of climate variability thereby protecting the soil from losing it nutrients.			
34. Crop diversification cannot be used to reduce the effects of climate variability.			
35. Using of stress tolerant and drought resistance cultivars can mitigate the effects of climate variability			
36. Exogenous application of protectant such as phytohormones can have beneficial effects on sugarcane and alleviate the effects of climate variability			
37. Building water harvesting scheme can reduce the stress of unavailable water during intense drought conditions.			
38. Changing dates of planting and methods can lessen the effects of climate variability on sugarcane.			
39. Reduction in sugarcane thrash burning can help climate variability effects			
40. Use of irrigation to supplement natural rainfall helps to increase sugarcane production.			
41. Sugarcane residue from past production can be used to suppress weed growth and improve soil structure and organic matter content on sugarcane farms.			

42. Using mulching on sugarcane farming improve water use efficiency by preventing evaporation of moisture.			
43. Sugarcane trash can be used to control water and wind erosion that occurs as a result of climate variability			

44. Do you rely on your indigenous knowledge regarding climate variability and adaptive strategies?

Yes (   )   No (   )

45. What are your indigenous climate indicators?

	List of indigenous indicators	Its uses
1.		
2.		
3.		
4.		
5.		

46. Does your indigenous climate knowledge level make a difference in your sugarcane production?

Yes (   )   No (   )

47. Where did you acquire climate indicator knowledge from?

Passed down to you (   )   Gained through personal experienced (   )   formal education (   )
Other Others (please specify) ………………………….

ADAPTATION STRATEGIES UTILIZED

48. What adaptation strategies have you used?
Indicate your level of utilization of the following adaptive strategies in your sugarcane farming activities.

Strategies	Not Used	Moderately used	Highly used
49. Efficient use of irrigation systems			
50. Drought resistant sugarcane varieties			
51. Changes in harvesting and planting dates			
52. Use of manuring on sugarcane farm			
53. Practicing crop diversification			
54. Building water harvest scheme			.
55. Mixed cropping			
56. Finding off-farm jobs			
57. The use of chemical fertilizer			
58. Improve in water maximization.			

59. Do you receive the support you need to sustain these adaptation practices?
Very less support ( ) less support ( ) adequate ( ) More support ( )

60. What kind of support would you need more of to be able to adopt to current and future climate variations?
Technical support to manage farming ( ) Technical support for disaster, risk reduction management( ) Financial support ( ) Education on climate variability and change( ) Education on improved/resilient farming practices( )
Other (please specify) ______________________________

……………………….THANK YOU………………………………

APPENDIX 2: KEY INFORMANT INTERVIEW SCHEDULE

UNIVERSITY OF MPUMALANGA

FACULTY OF AGRICUTURE AND NATURAL SCIENCES

SCHOOL OF AGRICULTURAL SCIENCES

KEY INFORMANT INTERVIEW SCHEDULE

TOPIC: PERCEIVED-EFFECTS OF CLIMATE VARIABILITY AND ADAPTIVE STRATEGIES UTILIZATION AMONG SMALLHOLDER SUGARCANE FARMERS IN NKOMAZI, SOUTH AFRICA.

Interviewed serial no:	

My name is Mr. XPP Nkosi, and I am a student at the University of Mpumalanga Student no: 201625474. I would like to ask you questions about your personal experience, opinion, and knowledge on the effects of climate variability and some adaptive strategies employed by smallholder sugarcane farmers as a coping instrument. This interview is for the above stated study which is specifically for academic purpose. This interview outcome will provide information for academics, researchers, extension agencies and governments on how best to improve smallholder sugarcane farmers adaptability to climate variability. The interview should take about 30 minutes.

All information obtained from this interview shall be treated with all the confidentiality it deserves and shall be used solely for the purposes of this study. Feel free to answer all the questions with as much knowledge and truth as possible. Your participation in this study is voluntary and you have the right to withdraw at any stage without any penalty.

Researcher Participant consent

I hereby declare that I fully understand the purpose and nature of the research interview. All my questions have been answered satisfactorily and I agree and consent to voluntarily participate in this academic research study.

Respondent’s Signature ……………………………… Date…………………...

<u>INTERVIEW SCHEDULE FOR KEY INFORMANT</u>

1. **What are some of the effects of climate variability you have experienced in the last 3-5 years?**

____
____
____
____
____
____
____
____
____
____

2. **What is your opinion on the capacity and knowledge of smallholder sugarcane farmers in adapting to the effect of climate variability?**

____
____
____
____
____
____
____
____
____
____

3. **What are some of the adaptive strategies smallholder sugarcane farmers have employed to cope with climate variability on their farms?**

____
____
____
____
____
____
____
____
____
____

4. **What kind of support have smallholder sugarcane farmers received from (government or private sector) that has enabled them to cope with the effect of climate variability?**

5. **As an experienced smallholder sugarcane farmer / please mention some of the challenged that you are currently still facing due to climate variability?**

6. **What do you suggest are possible solutions to ameliorate some of these challenges?**

>>>>>>>>>Thank you for your time and participation and cooperation. <<<<<<<<<<

APPENDIX 3: CERTIFICATE OF APPROVAL -RESEARCH PROPOSAL

UNIVERSITY OF MPUMALANGA

FACULTY OF AGRICULTURE AND NATURAL SCIENCES

Postgraduate Studies Committee

Certificate of Approval – Research Proposal

Date of this Approval:	**20 October 2022**

Student Details

1	Student Name:	Nkosi, XPP
2	Student Number:	201625474
3	School	School of Agricultural Sciences
4	Degree Registered for:	MAgric
5	Date of First Registration:	2022
6	Supervisor(s):	Dr M. Matiwane Dr O. D. Olorunfemi

The research proposal entitled '**Perceived effects of climate variability and adaptive strategies utilization among smallholder sugarcane farmers in Nkomazi, South Africa**' has been evaluated and approved by the Postgraduate Studies Committee of the Faculty of Agriculture and Natural Sciences.

UNIVERSITY OF MPUMALANGA
CREATING OPPORTUNITIES
20 -10- 2022
OFFICE OF THE DEAN

Chairperson: Prof. Victor Mlambo

Signature:

Date & Official Stamp:

APPENDIX 4: RESEARCH ETHICS CLERANCE LETTER

Research Ethics Clearance Letter UMP

UNIVERSITY OF MPUMALANGA

Creating Opportunities

Office 206. Building 4. C/o R40 & D725. Private Bag X11283. Riverside Mbombela South Africa 1200.
Website: www.ump.ac.za | *Tel*: (013) 002 0196 | ***Email***: Estelle.Boshoff@ump.ac.za

RESEARCH ETHICS CLEARANCE LETTER

Ref: UMP/Nkosi/MAgric/2023
Date: 22 March 2023
Name of Researcher: Xolani Pennial Presence Nkosi
Student number: 201625474
Supervisor: Dr Mona Matiwane
Co-Supervisor: Dr Oluwasogo Olorunfemi
School / Department: School of Agricultural Sciences
Faculty: Faculty of Agriculture and Natural Sciences

RE: APPROVAL FOR ETHICAL CLEARANCE FOR THE PROJECT:
PERCEIVED-EFFECTS OF CLIMATE VARIABILITY AND ADAPTIVE STRATEGIES UTILIZATION AMONG SMALLHOLDER SUGARCANE FARMERS IN NKOMAZI, SOUTH AFRICA.

Reference is made to the above application.

I am pleased to inform you that the Chairperson has on behalf of the University of Mpumalanga's Research Ethics Committee, **approved ethical clearance** of the above mentioned study.

Please Note
Any alteration/s to the approved research protocol i.e. Questionnaire/Interviews Schedule, Informed Consent form, Title of the project, Location of the study, Research Approach and methods must be reviewed and approved through the amendment/ modification prior to its implementation.
The Ethical Clearance Certificate is only valid for a period of 3 years from date of issue.

Prof Estelle Boshoff
Chairperson: University of Mpumalanga's Research Ethics Committee for Human and Social Sciences.