VULNERABILITY ASSESSMENT OF SMALLHOLDER MAIZE FARMERS TO CLIMATE CHANGE RISKS AND WILLINGNESS TO ADOPT CLIMATE-SMART AGRICULTURE IN LIMPOPO PROVINCE, SOUTH AFRICA

BY

KOKETSO CATHRINE MACHETE

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SUPERVISOR: PROF M.P SENYOLO

CO-SUPERVISOR: DR L.S GIDI

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DECLARATION

I, KOKETSO CATHRINE MACHETE, declare that the mini-dissertation (**Vulnerability assessment of smallholder maize farmers' to climate change risks and willingness to adopt climate-smart agriculture in Limpopo Province, South Africa**) hereby submitted to the University of Limpopo in the partial fulfilment of the degree Master of Science Agriculture in Agricultural Economics has not been previously submitted by me for a degree at this or any other university; that it is my work in design and in execution and that all materials contained herein has been duly acknowledged.

Machete KC (Ms) 16/02/2024

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Signature Date

DEDICATION

To

Koketso Cathy Machete

In gratitude for your steadfast commitment strength, and ability to endure stress, pain, emotional journey as it is. Your belief in the power of knowledge has fueled a desire to explore new horizons and uncover deeper insights in academics. This dissertation is dedicated to you, a testament to the value of endurance, perseverance, and boundless possibilities it can unlock. Thank you for not giving up*!*

"Proverbs 16:9 -In his heart a man plans his course, but the LORD determines his steps"

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ABSTRACT

Maize holds an essential position of the primary grain crop in South Africa, being a significant source of feed for animals and staple food among rural communities. Due incompetent farming techniques that smallholder farmers frequently employ, maize is more susceptible to the effects of climate change, especially intense heat waves and irregular rainfall. South African smallholder farmers' need adjustment towards learning new farming techniques as they mitigate and adapt to changing climate. Hence, it becomes imperative to understand farmers' willingness to adopt Climate-smart agriculture (CSA) and factors influencing willingness to adopt CSA. This study aimed to examine the vulnerability of maize farmers to climate change risks and analyze their willingness to adopt (WTA) CSA by profiling their socioeconomic characteristics, assessing their vulnerability to climate change risks, and analysing socioeconomic factors influencing their WTA CSA. About 219 smallholder farmers were purposively selected using Purposive Snowball sampling method. Cross-sectional primary data was used where information was gathered using structured questionnaires by conducting face to face and Focused Group Discussions (FGDs). The study was conducted at Ga-Makanye, Gabaza and Giyani (Dzingidzingi village) located in Limpopo Province of South Africa. Measure of dispersion, Vulnerability Index Assessment, Double-hurdle model, and WTA through CVM were utilised to the research objectives. The study used mixed method to analyse the quantitative and qualitative data.

Results indicate that 81%, 67% and 63% of respondents were willing to adopt CSA in Ga-Makanye, Gabaza and Giyani, respectively. Gabaza and Giyani had more female farmers as compared to males with 77% and 70, 8%, respectively and Ga-Makanye had an equal gender distribution of sampled farmers. The results infer that a total of 75% were vulnerable to climate change risks such as relatively high temperatures with limited rainfall for a longer (drought). The econometric results were addressed using the Double-Hurdle Model and were statistically significant at 5%. Smallholder maize farmers' education, crop diversification, and information about CSA positively influenced the WTA CSA while agricultural experience and household size negatively influenced the WTA CSA. The study recommends that the Department of Agriculture,

Land Reform and Rural Development together with various agricultural stakeholders should enhance knowledge from extension officers within the area through provision of climate-smart agriculture workshops and education and encourage scientist to innovate new crops that suit CSA and farmers to diversity into new drought tolerant crops amongst other interventions.

Keywords: Vulnerability, Climate change, Climate Smart Agriculture, Ga-Makanye, Gabaza and Giyani (Dzingidzingi village)

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AES - Access to extension services

AFDB - African Development Bank Group

APP – Assistant Agricultural Practitioners.

BFAP - Bureau for Food and Agricultural Policy

CA – Conservation Agriculture

CCKP - Climate Change Knowledge Portal

CD - Crop diversification

CO_2 – Carbon dioxide

CSA – Climate-Smart Agriculture

CVM – Contingent Valuation Method

DAFF – Department of Agriculture, Forestry and Fisheries

EL – Educational level

FAO – Food and Agriculture Organization of the United Nations

FAOSTAT - Food and Agriculture Organization Corporate Statistical Database

FEWSNET - Famine Early Warning Systems Network

FGD – Focused Group Discussion

GHG – Greenhouse Gas

IC – Income diversification

ICSA – Information about CSA

ICT – Information and Communication Technology

IPCC – Intergovernmental Panel on Climate Change

IPI - International Peace Institute

KG/HA – Kilogram per hectare

KZN – KwaZulu Natal

Mm – Millimetre

NAMC – National Agricultural Marketing Council

NRF- National Research Fund

SA – South Africa

SSA – Sub-Saharan Africa

UNFCCC – United Nations Framework Convention on Climate Change

US – United State

USA – United States of America

WTA – Willingness to adopt

WTP – Willingness to pay

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Globally, climate change threatens economic sectors including wetlands, forestry, and agriculture, which in turn threatens these industries' profitability and production (Chipanshi et al., 2003; Mulwa et al., 2017; Etwire & Martey, 2020; Derbile et al., 2022). Climate change may be described as the addition of natural climate variability observable over a sufficient period of 30 years, plus changes that may be directly or indirectly connected to human activities that affect the composition of the global atmosphere (UNFCCC, 2011; Mhlanga, 2019). These changes mainly affect agricultural activities and production, particularly vulnerable smallholder farmers (Senyolo et al., 2021). Agriculture is mainly susceptible to these changes, and this makes main crops produced (such as maize) vulnerable to climate change risks.

Maize is considered as major food crop and staple food grain for households as it provides source of income for smallholder farmers in rural areas (Sihlobo, 2016; Etwire & Martey, 2020; Rudin, 2022). More significantly, according to Lacambra *et al*. (2020), maize is one of the crops that is most vulnerable to the effects of climate change. Not only maize is subjected to extreme weather, but smallholder farmers are also exposed to climate changes as they have limited access to resources and capacity to adapt to these risks (Harvery et al., 2011; Kamali et al., 2018). This necessitates for smallholder farmers to assess the impact of these risks through vulnerability assessment tool, which provides better understanding on determining alternative ways to cope with climate risks. Furthermore, climate change-related challenges dictate for smallholder farmers to implement climate-smart agriculture (CSA) practices, nonetheless, they have limited access to land and land ownership (DAFF, 2012; Masters, 2014; Makwela, 2021). According to FAO (2010), Gwambene *et al*. (2015) & Torquebiau *et al.* (2018), CSA is a strategy to support agricultural systems globally while concurrently addressing three challenge areas through enhancing agriculture's resilience to climate change, mitigating its effects (by enabling the farming sector to seize greenhouse gases), and guaranteeing global food security through creative financing, policies, and practices.

Many studies have indicated that the key solution towards reducing risks imposed and challenges caused by climate changes as a goal driver towards improving smallholder farmers' production and food security is through adoption of Climate Smart Agriculture (CSA) practices/technologies (Mazibuko, 2018; Senyolo et al., 2018). However, CSA adoption remained relatively low by peasant farmers in Sub-Saharan Africa (SSA) (Sinyolo, 2020). This is due to high costs associated with this adoption and limited knowledge about these CSA practices (Kangogo et al., 2021 and Makamane et al., 2023).

1.2 Problem statement

According to Lacambra *et al*. (2020), maize is the most widely consumed grain crop in South Africa since it is a staple diet for rural communities and a major source of feed for livestock. However, the methods of maize farming leave the crop sensitive to a changing climate, notably severe heat, and unpredictable rainfall (Ayinde et al., 2018; Kimaro et al., 2018). Reasons for smallholder maize farmers' vulnerability is largely because their production of maize relies on rainfall (Mpandeli et al., 2015; Mdungela et al., 2017; Senyolo et al., 2021a). Hence, erratic rainfall puts smallholder farmers at the disadvantage when compared with their counterparts, large commercial farmers', who may have access to irrigation prospects to deal with the erratic rainfall situations (Lemma, 2016; Zwane, 2019). Prior studies suggested that CSA could be a viable way to address issues related to climate change (Senyolo et al., 2021b).

In accordance with Derbile *et al*. (2022), the maize crop is extremely vulnerable to the effects of climate change. In the words of Kangogo *et al*. (2021), Musafiri *et al*. (2022) and Ogunyiola *et al*. (2022), smallholder maize farmers' need to implement a variety of mitigation and adaptation techniques for climate change, including CSA. CSA encompasses tactics and managerial approaches aimed at enhancing agriculture to attain food security, bolstering the resilience of farmer households to climatic variations, and contributing to climate change mitigation. This involves capturing carbon in biomass and, where feasible minimizing emissions (Kimaro et al., 2018). Among the CSA practices include crop rotation, using drought-tolerant maize crop and using crop modeling technique among others. When compared to industrialized, wealthy nations, the adoption of CSA technologies is still generally low, especially in Southern African countries (Kurgat et al., 2020; Serote et al., 2021). According to Gwambene *et al*. (2015), most farmers are willing to implement CSA, but they lack the capacity to do so. These authors indicated that the adoption is lower than the willingness to practice in Tanzania because it is a Southern African country (Gwambene et al., 2015).

The proposed theory of the study is that farmers are more susceptible to the negative effects of climate change, but they lack management plans or coordinated efforts, and even those who are aware of the climate changes find it difficult to adjust for a variety of variables that the study will identify (Ayinde et al., 2018; Matimolane, 2018; Remilekun, et al., 2021). Thus, the purpose of this research is to assess the climatic risk and vulnerability risk that smallholder maize farmers tackle on their farms and the variables that affect their willingness to participate in mitigation and adaptation strategies such as CSA.

1.3 Rationale of the study

The South African agricultural sector is dual in nature, comprising the low productive sector (i.e. smallholder sector) and large-scale sector (Pienaar & Traub, 2015). Therefore, this dualistic nature, makes it more difficult to have improved productivity and enough funds to mitigate against climate change impacts, specifically within the smallholder sector. Agriculture generally contributes significantly to the number of jobs available in rural regions and the reduction of poverty in the province of Limpopo (Baloyi, 2010). However, it is extremely vulnerable to the hazards associated with climate change (Letsatsi-Duba, 2009; Maponya & Mpandeli, 2012). There is a need to encourage farmers to assess the risk of climate change and adapt to these risks by adopting alternative measures. Furthermore, Fellamann (2022) noted that farm vulnerability assessment is one of the critical techniques that may be used to examine various approaches to climate change adaptation and mitigation. Consequently, maize crops are most sensitive and vulnerable to drought and extreme temperatures (Derbile et al., 2022). Similarly, maize production depends on availability of water henceforth, South African agriculture is considered as rain-fed dependent especially among the rural smallholder farmers (Mulungu & Ng'ombe, 2019). This tool can also be used to analyse the many techniques and practices that farmers might apply to adapt to the significant and ongoing changes in climate circumstances. South African smallholder farmers must adjust towards learning new farming techniques as well as acquiring new related to CSA (Ogunyiola et al., 2022) ensuring food security and poverty reduction in rural area.

Farmers must be able to recognize the climate change before they can decide how to adapt and cope (Ubisi, 2016). Despite the benefits to farmers', adoption of CSA methods is not inevitable, and further research on variables influencing desire to embrace CSA is needed (Abegunde et al., 2019). Therefore, this study will contribute towards improved understanding of smallholder farmers' ways to mitigate against climate risks and CSA adoption in rural areas of Limpopo Province by using farm vulnerability assessment and describing socioeconomic and factors that may hinder the willingness to adopt CSA practice such as crop insurance, rain water harvesting, drought-tolerant maize seeds, crop rotation, crop diversification, site specific nutrient management, conservation agriculture and among others. The adoption of CSA will contribute towards sustainable agriculture and development (Sarker et al., 2019).

1.4 Scope of the study

1.4.1 Aim of the study

The aim of the study was to examine vulnerability of maize farmers towards risks of climate change and analyze the willingness to adopt climate-smart agriculture (CSA) in Limpopo Province, South Africa

1.4.2 Research objectives

i. To profile socioeconomic characteristics of smallholder maize farmers in selected areas of Polokwane, Tzaneen, and Giyani Municipalities of Limpopo Province.

ii. To assess smallholder maize farmers' vulnerability to climate change risks in selected areas of Polokwane, Tzaneen and Giyani Municipalities of Limpopo Province, South Africa.

iii. To analyse socioeconomic factors influencing smallholder maize farmers' willingness to adopt CSA in selected areas of Polokwane, Tzaneen and Giyani Municipalities of Limpopo Province, South Africa

1.4.3 Research hypotheses

i. Smallholder maize farmers in selected areas of Polokwane, Tzaneen and Giyani municipalities of Limpopo Province, South Africa are not vulnerable to climate change risks.

ii. Smallholder maize farmers' socioeconomic characteristics do not significant influence their willingness to adopt CSA in selected areas of Polokwane, Tzaneen and Giyani municipalities of Limpopo, South Africa.

1.5 Structure of the study

The study's background, the problem statement, and the motivation of the study were all covered in Chapter 1. In addition, this chapter included an outline of the study's purpose, objectives, and guiding hypotheses. In the second chapter, a review of the literature was presented, with a particular emphasis on national and international research on the desire of smallholder maize farmers in South Africa's Limpopo Province to adopt climate smart agriculture and how vulnerable they are to the risks associated with climate change. The research methodology of the study was presented in Chapter 3, including the study areas, sampling frame and processes, analytical methodologies, types of data used, and methods of data collection and analysis. The study's measure of dispersion (descriptive statistics) findings was presented in Chapter 4. Additionally, Chapter 5 presents and expands on the vulnerability assessment results and econometric findings was presented and discussed. The research summary, conclusion, and recommendations were included in Chapter 6. Thus, this chapter presents the study's overall summary, conclusion, and suggestions based on the data gathered from the investigation.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

"The work that you do is not done in a vacuum, but it builds on the ideas of other people who have studied the field before you. This requires you describing what has been published, and to marshal the information in a relevant and critical way" (Jankowicz, 2005). In this chapter, a literature review pertinent to the present study is provided. For this reason, the chapter covers studies related to smallholder farmers' vulnerability, climate change related impacts and climate smart agriculture as an approach to address challenges relating to climate change. Furthermore, the chapter covers various studies related to the topics. It seeks to first define key concepts, review continental maize production, history of maize in Africa, South African maize production, Climate and Agriculture, Climate-smart agriculture, and Contingent valuation method.

2.2 Definition of key concepts

2.2.1 Vulnerability

The concept of vulnerability has been widely used by different fields of specialization or disciplines with different definitions including how it affects the subject matter (Freshwater, 2014). In the discipline of economics, vulnerability is mainly associated with a level of risk linked with physical, social, and economic factors, as well as implications deriving from the system's ability to deal with the occurrence as well as uncertainty which mainly affects productivity and profitability (Proag, 2014**;** Choudhary & Sihori, 2022). In this study smallholder farmers' vulnerability refers to sensitivity and exposure to climate change risks that affect productivity and profitability.

2.2.2 Smallholder farmers

Makwela (2021) outlined that the description of a smallholder farmer differs from one location and farming system intensification to another. Smallholder farmers were outlined as those farmers who are resource-poor, and occasionally "peasant farmer" (Mnkeni et al., 2019) who produce for household consumption and markets, subsequently earning on-going profits which mainly form a source of income for their families (DAFF, 2014 & Makwela, 2021). Smallholder farmers are referred to in this research as households that cultivate agricultural commodities on small areas of land

and have limited resources for production. The primary purposes of these farmers' production are consumption and, in the event of excess produce, results in income.

2.2.3 Climate change

Climate change refers to long-term patterns of increasing average global and regional temperatures, precipitation, and humidity as assessed by quantitative methods, as well as variations in the intensity and occurrence of climate spanning months, decades, and even centuries (Lineman et al., 2015; Naicker, 2018; Thornton et al., 2014). Climate change has placed a threat on smallholder farmer's productivity and production (Wilson et al., 2022). This threat has been causing negative shocks for the food production, affecting harvest and yields. Additionally, climate change has affected rural smallholder farmers in negative way as these farmers rely on rainfall for harvest and natural resources for production (Zhang et al., 2022).

2.3 Maize Production

2.3.1 Global Maize production

Valley of Mexico) in the Southern American continent about 9000 years ago (Ranum et al., 2014). Initially, it originated from a grass called *teosinte* (Scheltema et al., 2015), which was then transformed by the native Americans to become maize that is consumed as a better source of food for households and trade purposes (Awika, 2011; Ranum et al., 2014; Kennett et al., 2020). In accordance with FAOStat (2021), there are 197M ha of maize grown worldwide for only dry grain. This area includes significant parts of Asia, Latin America (South America), and Sub-Saharan Africa (SSA) (Erenstein et al., 2021). Moreover, in regions such as SSA, Latin America, and a few countries in Asia, maize is considered an established and substantial human food crop due to its widespread consumption by numerous households (Shiferaw et al., 2011; Ranum et al., 2014; Ekpa et al., 2019). Mazie is a more adaptable, multipurpose crop since it may be used for various things, including food, animal feed, and fuel (Shiferaw et al., 2011). In conclusion, it has been stressed that maize plays various dynamic roles in international agri-food systems and food security (Grote et al., 2021; Poole et al., 2021; Erenstein et al., 2021). The production of maize will be required to be increased by 70% by the year 2050, as reported by various studies (Cairns et al., 2021). FAOSTAT (2021) stated that maize constitutes a a higher part of SSA as a principal staple crop, which covers approximately 27M ha.

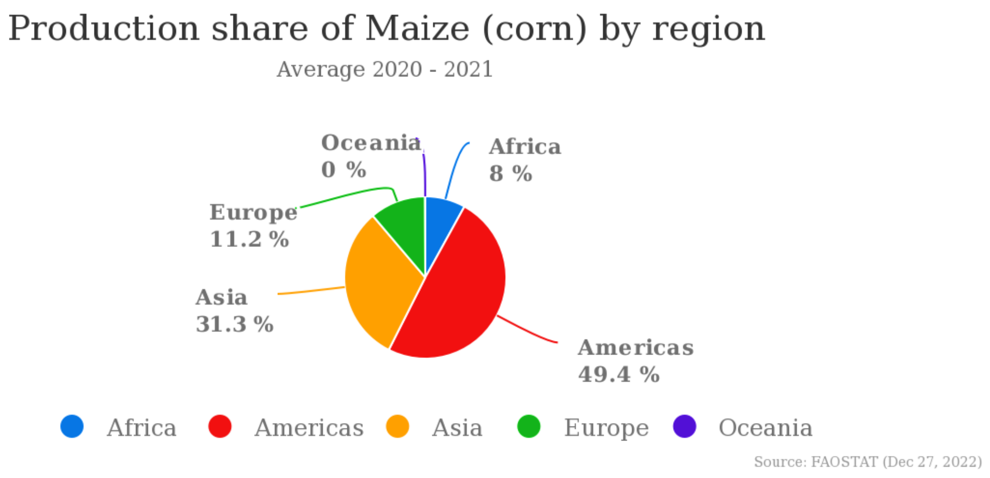

Figure 2.1: Continental production share of maize (corn) by region (Average 2020 – 2021)

Source: FAOSTAT (2022)

Figure 2.1 depicts overall maize (corn) production share by region, namely Africa, Americans (North America, Central America, and Southern America combined), Asia, Europe, and Oceania. In accordance with FAOSTAT (2022), Americans account for the highest percentage of maize output when divided across three areas (49, 4%), with Asia accounting for the second largest (31, 3%). Africa (8%) and Europe (11, 2%) produce the least amount of maize. Americans have increased their maize output share through improved farming methods and selective breeding of corn, which includes adjusting to better farm-management practices such as more effective fertilization (Borunda, 2022). According to International Peace Institute (IPI) (2007), the fast adoption of higher yielding maize varieties (hybrids, open pollinated varieties, and traditional) across Asia has resulted in considerable yield increases in favourable rain-fed and irrigated maize growing areas (see Figure 2.1). Furthermore, access to adequate funds has led to farmers in Asia employing hybrid varieties despite higher seed prices, allowing them to implement superior crop management methods, resulting in increased maize yield.

Africa produce less maize as compared to other regions due to smallholder farming system is associated with peasant farmers faced with little access to technological systems and agrochemicals such as fertilizers (Bradshaw et al., 2022; Epule et al., 2022) harsh climatic conditions such as extreme temperatures which leads to droughts and flooding. Additionally, limited farming skills and lack of climate-smart technologies contributes to low maize yields produced in Africa (Boayke, 2023).

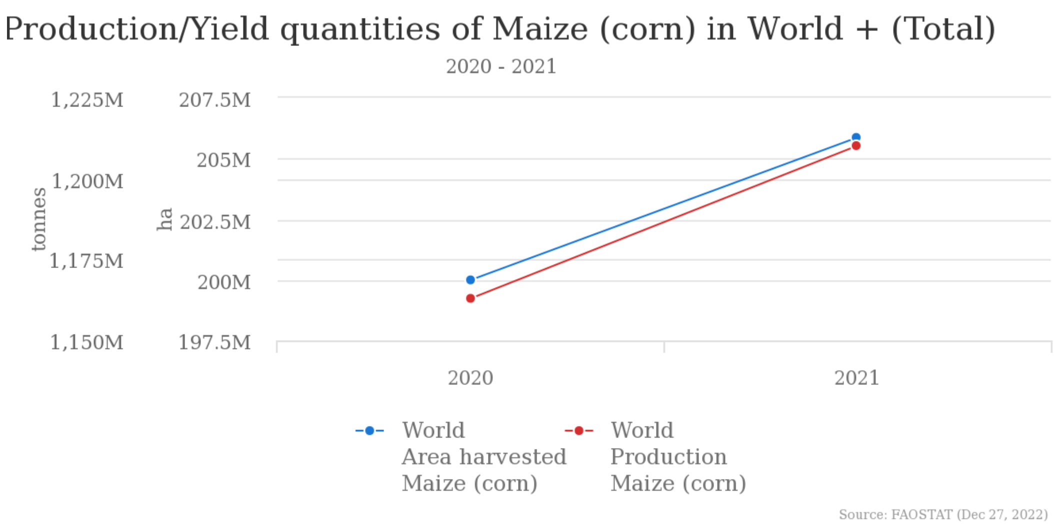

Figure 2.2: Production/Yield quantities of maize in the World

Source: FAOSTAT (2022)

Global production and yield amounts of maize are shown on Figure 2.2. According to FAOSTAT (2022), the world area harvested of maize in 2020 was 199M ha, while in 2021 it increased to 205M ha. As stated by Mutengwa *et al*. (2020), Americans and China dominate maize production, accounting for more than half of world maize output. Maize grain production is affected by soil genetic traits, field management techniques, and agro-climatic conditions (Jocković et al., 2010**;** Alovi, 2014; Mutengwa et al., 2020). This demonstrates that such variables contributed to an increase in maize harvested globally. Furthermore, Figure 2.2 shows that the global maize population in 2020 was 1162M ha, which positively increased in 2021 to 1210M ha (FAOSTAT, 2022).

2.3.2 African Continent Maize Production

According to Cherniwchan & Menero-Cruz (2019), maize initially arrived in Africa during the 17th century. The crop was adopted by many African farmers as it had high energy production and has minimum labour needs and had a brief growing season. Maize is a major and important grain crop in Africa, particularly in Eastern, Southern, Central, and Western Africa (Etwire & Martey, 2020), and it is considered as the second most cultivated crop in the continent (Epule et al., 2022). Furthermore, maize in Africa accounted to about 8% of total production share in 2021 (FAOSTAT, 2022).

Since smallholder farmers in the continent are resource poor, this could be part of the reasons why most of them opt for maize produced for consumption, and very little is reserved for commercial purposes. In addition, as it is cultivated by peasant farmers, they mostly depend on increasing the harvested area as an approach to improve production (Epule et al., 2022; Boayke, 2023).

Agriculture in Africa remains vulnerable to climate change considering that the continent's agricultural system mainly depends on rain, it could be with few inputs available to achieve successful adaptations of agricultural systems to the changing climatic conditions (Parker et al., 2019; Derbile et al., 2022). Consequently, it results in maize yields in Africa remaining relatively low, accounting to less than 3000kg/ha as compared to other producing countries and developed countries. Countries such as Zimbabwe, Malawi, and Mozambique in the SSA have been negatively affected by climatic conditions such as dry weather and droughts, which decreased maize production (Mlungu, 2019). On the other hand, KwaZulu Natal (KZN) and other provinces in the Eastern Cape (EC) of South Africa have had increased rainfall in recent years (Molekwa, 2013). Anekwe et al. (2023) report that South Africa had heatwaves, droughts, and heavy rainfall that resulted in flooding and storms over the 2021–2023 period, because of climate change. The excessive rainfall was caused by La Nina storms consequently affecting harvest and production (Ngcamu, 2023). In the Southern Africa, most of the cultivated land is rain-fed agriculture due to limited resources and scope for development of proper irrigation systems, making farmers in the region to mostly rely on rain for their crops (Winsemius et al., 2014).

Many of the semi-arid areas that make up Southern Africa are favoured by inter- and intra-annual climatic fluctuation (Spear et al., 2015). Owing to extremely rapid increase in global climatic conditions, Africa is not also immune to the changing climatic conditions (Pickson & Boateng, 2022), suggesting that its production may continue to fluctuate. Maize is mostly planted in countries within the Southern African (South Africa, Botswana, Zimbabwe and among others) west Africa (e.g. Nigeria dominating the production in the western parts of Africa), East of Africa (Ethiopia), and North Africa dominated by Egypt as major producer of the crop in the North (Ekpa et al., 2019; Tadesse et al., 2019; Erenstein et al., 2021). Africa alone produced 7% of total maize output in 2017, which was 84.2M tons (FAOSTAT, 2022). It has been reported that in 2018 the maize output accounted for about 7, 5% of the world maize production

(Woomer et al., 2023). Maize has occupied close to 24% of the arable land in the continent, likewise, 37M ha is normally planted every year (du Plessis, 2003). Between 2017 and 2022, Africa's maize production had increased by over 8, 2%, or 90.8M metric tons harvested.

Maize crop plays a crucial role towards the continental food security as it is considered a staple food for societies because it is cheap and easily accessible (Hlatshwayo et al., 2023). Furthermore, it is a significant crop as it contributes towards poverty alleviation and achieving food security through providing source of income for rural livelihoods (Hlophe-Ginindza & Mpandeli, 2021). In emerging and poor nations, particularly African countries, the crop is used in various forms namely, as roasting green maize, making steamed products (dumpling in South Africa), porridge (soft porridge used for breakfast meal and pap mainly in SSA while 80% of maize is used for food and 40% is used for cereal (Ekpa et al., 2021). The crop not only provides to food, but it also acts as an important source used for improving health through nutraceuticals that are known to protect against diseases caused by other maize, such as carotenoids and phlobaphene’s (Selna, 2016). Maize also serves as a major feed grain for animals, it serves 60% energy needed for animal growth and maturity (Qi et al., 2017). Maize as an animal feed plays a vital role in providing carotene (vitamin A) in livestock (Dei, 2017). This is important for production as livestock sector plays an essential role in the economy of some African countries including South Africa.

2.3.4 South African maize exports and imports

Townsend *et al*. (1997) and Matji (2015) reported that South Africa was once self-sufficient in food items and a significant exporter of grain crops, including maize. It became a major exporter of maize in 2011/2012 season however during season of 2013/2014 it had the highest export earnings of R7.3 billion and exported about 2.6M tons of maize produced (Sihlobo & Kapuya, 2015). Ultimately, with favouring weather conditions such as adequate rainfall in some parts of the country it has increased its total harvested area and production yields (Shew et al., 2020). The country was reported to remain the major net exporter for an estimated 3.2M tons of maize in year of 2022/2023 with white and yellow maize projected at 7, 5M tons and 7,1M tons, respectively (NAMC, 2021). Although, during 2021/2022 the country exported more maize at about 4, 1M tons which indicated a major drop in 2022/2023 production season. Moreover, maize in the past decades has been one of the most significant crops in South Africa, as it serves two main purposes; being major feed grain and staple food for livestock and households, respectively (Gronte et al., 2021; Rudin, 2022). In the country, maize crop is produced for various reasons; it serves as both cash and food crop and plays an important role in food security (Hlophe-Ginindza & Mpandeli, 2021). The crop has accounted for 22-25% of starchy stable consumption in African continent since 1980, and it represents the largest single source of calories consumed (Smale et al., 2011). An average consumption of maize in South Africa and other countries like Lesotho, Malawi, Zimbabwe, and Zambia is up to 450g/person/day (Ekpa et al., 2021). White maize is mainly consumed by households as processed mealie meal while yellow maize is used as a feed grain for livestock particularly, for poultry production (Makgobokwane, 2019; Jordaan, 2022; Kriel, 2022)

Maize was grown mostly in South Africa's high-veld provinces, including Gauteng, Free State, Northern Cape, Mpumalanga, North-West, and Limpopo. This is because the high-veld regions are characterized by summer rainfall, which occurs between October and March (Matji, 2015). High veld is described as the elevated terrain of eastern South Africa bounded by 1, 350 m (Simpson & Dyson, 2018). South Africa's average annual rainfall is roughly 464 mm, with the Western Cape receiving most of its rainfall during the winter (June to August), and the rest of the country receiving rainfall during the summer (December to February) (Climate Change Knowledge Portal (CCKP), 2021). Under those circumstances, drier western parts in highveld regions rainfall are the major limiting factor towards crop development (Matji, 2015).

Maize crop requires more water and irrigation; however, South Africa's water shortage means that man can only partially control output through irrigation, which costs significant startup expenditure. (DAFF, 2017). Moreover, the crop can be cultivated on an area where rainfall distribution is higher than 350 mm per year (GrainSA, 2017). However, South African climatic conditions differ in terms of rainfall distribution patterns and variabilities (Botai et al., 2018), which amounts for rainfall that is received at different regions, consequently, making farmers exposed to climate change differently (Mazibuko, 2018). In consonance with Baloyi (2010), maize is produced throughout South Africa, whereby it is mainly planted on dry land, however, that is 10% and less of that is being harvested under irrigation. In South Africa, maize is grown under various agro-ecological climate conditions (e.g., soil types, rainfall, temperature, and water availability) by subsistence, smallholder, and commercial farmers (Hlophe-Ginindza & Mpandeli, 2021).

According to Wettstein *et al*. (2017), between 2006 and 2015, an average of 11M tons of maize were produced yearly on 2, 6M ha of land. Furthermore, in 2012, South Africa produced 17% of its yellow maize and 8% of its white maize under irrigation (Mnkeni et al., 2019). Comparably, in 2022 total production of white maize was 12, 17% with a yield of 4, 80 t/ha, while overall production of yellow maize was 7, 06% with a yield of 6, 84 t/ha (DALRRD, 2022). Nevertheless, there is a small portion of land that is used to enhance crop production due to the arid climatic conditions experienced (Wettstein et al., 2017). Recently in 2022, there have been more rainfall experienced between October and November months. Figures 2.3 and 2.4 exemplify rainfall (mm) experienced in October and November 2022, in accordance with reports, October 2022 experienced near-normal to above-normal rainfall, with the most of it falling in the Eastern Cape, KwaZulu-Natal, Free-State, Gauteng, Mpumalanga, Limpopo, and North-West provinces. Limpopo and KwaZulu-remote Natal's regions also saw some degree of dryness (SAWS, 2022). On other hand, in November there was high rainfall in Limpopo, Gauteng, Kwazulu-Natal, Northwest and some part of Eastern Cape Provinces. Moreover, this demonstrates that during the planting season for maize, which is late October to Mid-December there was adequate rainfall for production and higher yields.

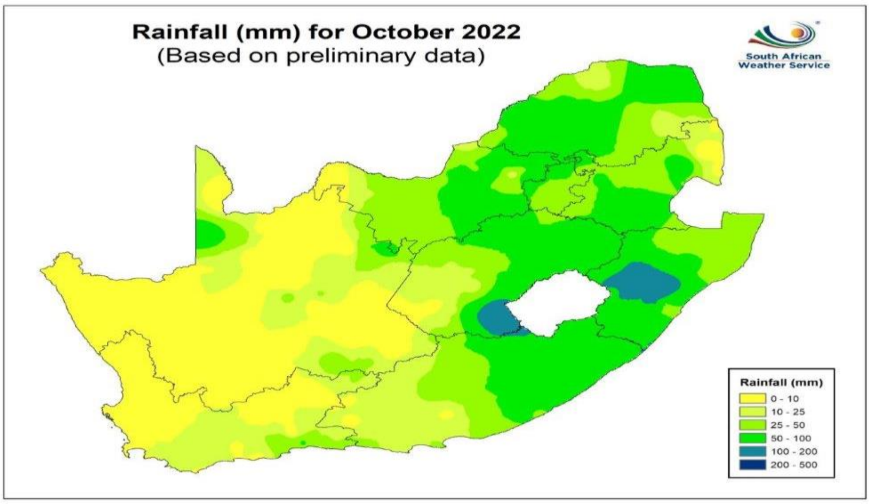

Figure 2.3: Rainfall (mm) for October 2022 based on preliminary data in South Africa

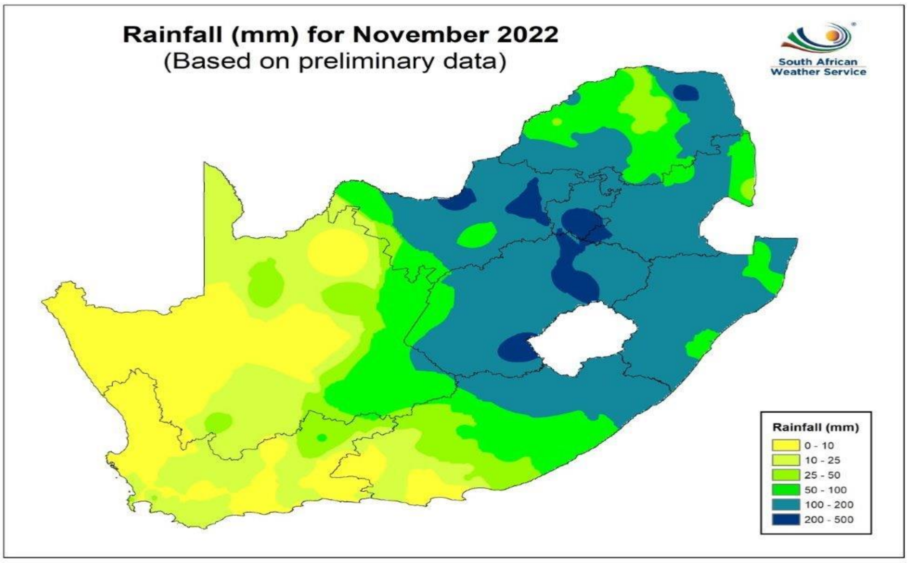

Figure 2.4: Rainfall (mm) for November 2022 based on preliminary data in South Africa

Source: South African Weather service (2022)

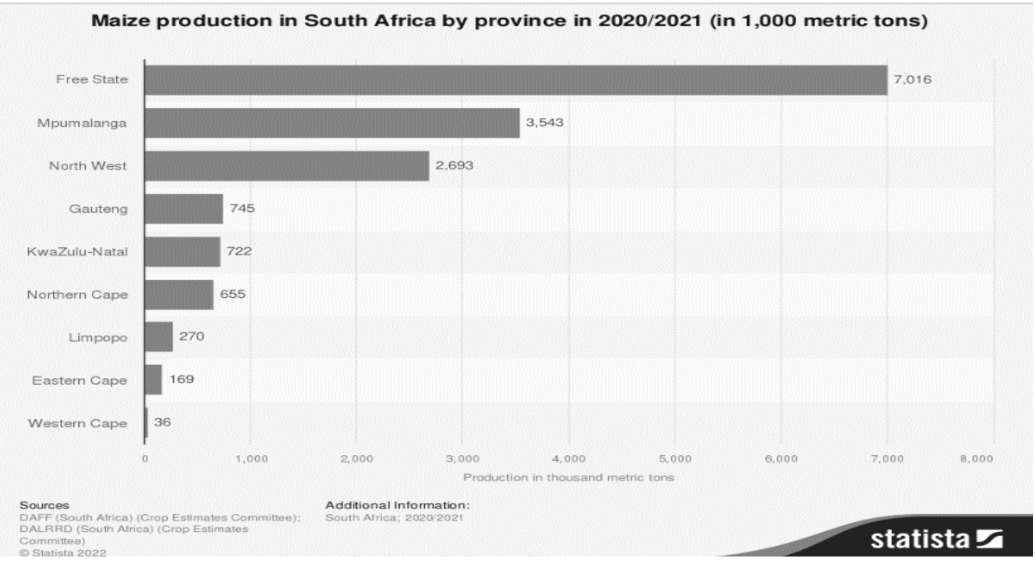

Figure 2.5: Maize production in South Africa by province in 2020/2021 (in 1000 metric tons)

Source: Statista (2022)

Figure 2.5 illustrates the South African maize production by province in 2020 and 2021. According to Statista (2022) it was estimated that in 2020 and 2021, the total maize production in South Africa had increased by 15, 8M metric tons with Free State Province as the highest producing province with 44, 3% (7, 016 metric tons) of the overall maize production. Mpumalanga and North-West become the second and third leading provinces with 3, 543 metric tons and 2, 693 metric tons of maize produced, respectively. Limpopo, Eastern Cape, and Western Cape become the least three provinces with lowest overall production of maize in 2020/2021.

The economic impact of climate change in South Africa is related to many aspects concerning changes within the agricultural sector, hence, there is an impact on the national income of citizens' livelihood (Turpie et al., 2002). Due to climate change-related challenges, the agricultural sector will experience a decline in the gross domestic product (GDP), moreover, and through the GDP the sector enhances the country's job opportunities and foreign exchange earnings through exports (Campbell, 2022). In the year 2018/19, the maize GDP was R28B, which is an increase of about 15% as compared to the year 2017/18 (FAOSTAT, 2009). Higher maize yields and output is manipulated by quality produced, which can also be affected by socioeconomic factors such as lack of knowledge caused by no educational training (Ramogodi & Pelser, 2020).

2.4 South African Maize Production

As reported by Erenstein *et al*. (2021), there is a global trade in maize, with 15% of the crop exported worldwide—a growth from 11% a decade before. South Africa is among countries that are considered as top maize net-exporters from quarter century ago, together with other developed countries including USA, France, Argentina, and China were each export 1 to 45M tons per year (FAOSTAT, 2021). On the other hand, adverse weather patterns impact worldwide agricultural yield in main crops like maize and breadbaskets, resulting in concomitant global agricultural failures and consequences (Gaupp et al., 2020).

According to Sihlobo (2016), maize production in South Africa provides many opportunities such as contributing to poverty alleviation, employment creation, livelihoods improvements and contribute a substantial contribution to the nation's economy, both in terms of supplying input industries and supporting processing industries downstream. This includes exports and imports, which ensures revenue generation for the government (Campbell, 2022). South Africa was a primary maize exporter to nations Like Zambia, Zimbabwe, Mozambique, Botswana, and Malawi establishing its significant role in exporting maize within SSA countries (Matji, 2015). Greyling & Pardey (2019) concurred that an average of 25% of the country's maize is exported mostly to the Southern African neighbouring countries. The competitiveness of the maize sector is a priority since it is crucial to the South African economy and the nation's food security (Sihlobo, 2016).

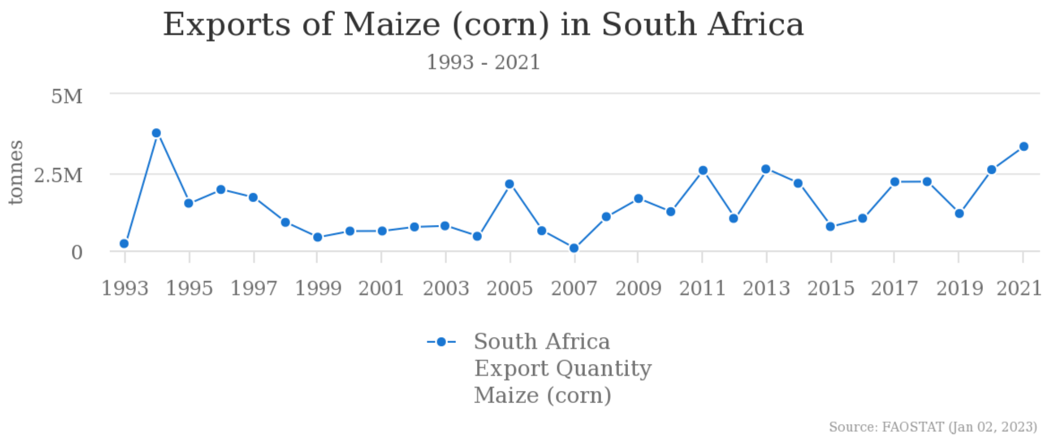

Figure 2.6: Exports of maize (corn) in South Africa (1993 - 2021)

Source: FAOSTAT (2023)

Figure 2.6 demonstrates the total maize exports in South Africa from the year 1993 to 2021. Based on FAOSTAT (2023) report, South Africa's maize exports were initially low in 1993 because the General Agreement on Tariffs and Trade (GTT) in Marrakesh opened the maize sector to the influence of the global market. In the end, this occurred after government restrictions on agricultural trade were replaced with tariffs (Sihlobo, 2016). Moreover, the maize business was significantly impacted by South African trade policy before to 1994, which included surcharges, tariff lines, advalorem levies, and quantitative limits (Greyling et al., 2015).

These controls reduced the quantity of maize exported as there were standards and regulations to be met by farmers (Erenstein et al., 2021). In 1994, the quantity of maize exported increased to 3M ha/tons due to GTT and other regulatory institutions, which were established to implement the trade policy reform introduced. This was done to enhance maize trade in South Africa including International Trade Administration Commission, Food Safety and Quality Assurance, South African Agricultural Food, Perishable products Export control Board (Sihlobo, 2016). According to FAOSTAT (2022), the South African export quantity in 2020 was 2M tons of maize, which significantly increased from 1994/1995. During 2015/2016 production season, the country imported more maize than it exports due to climatic risks such as drought experienced, as such it reduced the maize output and surplus produced (Sihlobo &

Kapuya, 2015). Wherein, in 2021, maize exported positively increased to 3.2M tons, indicating more surplus produced during that production season (Statista, 2022)

Recently the ongoing conflicts in Ukraine, which is one of the net exporters of fertilizers has had a negative impact on the local prices and availability of fertilizers in South Africa resulting in high production costs for South African farmers (NAMC, 2022). Smallholder maize farmers primarily depend on the production of maize for both consumption and revenue; therefore, Ukraine crisis had a detrimental effect on their way of life. Furthermore, the same farmers are also subjected to high production costs, as a result, affects the surplus produced.

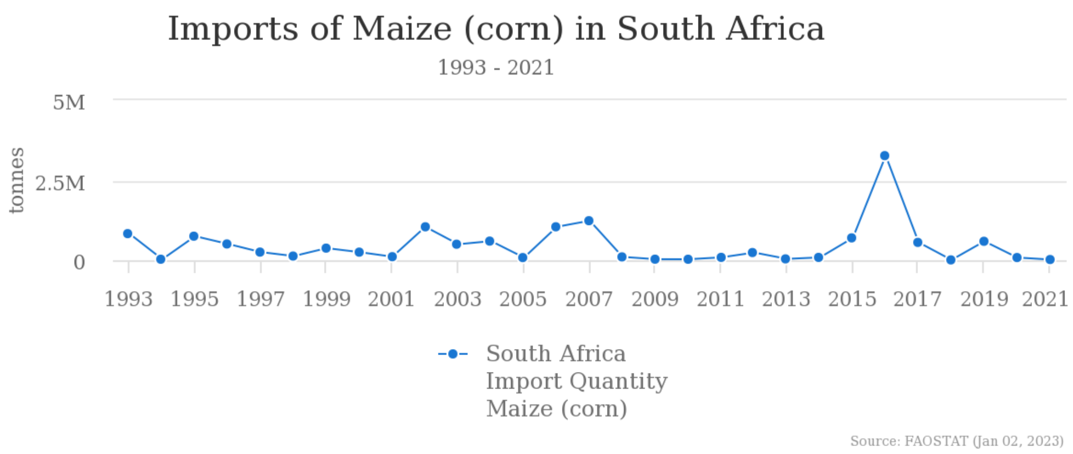

Figure 2.7: Imports of maize in South Africa (1993 - 2021)

Source: FAOSTAT (2023)

Figure 2.7 illustrates the imports of maize in South Africa from the year 1993 to 2021. As attested by FAOSTAT (2023), the South African maize imported in 1993 was 830, 242 tons, while, in 1994 maize imported negatively reduced to 29, 760 tons. There are assorted reasons, which were recorded towards this reduction in maize imported. The Bureau for Food and Agricultural Policy (BFAP) (2014) reported that in 2007, quantity of maize imported had reduced due to severe drought that affected the country as well as Lesotho. Notably, in 2015 and 2016, maize imported had increased and this was due to climatic condition such as prolonged drought period and pest invasion that had affected agriculture (Mulungu & Ng'ombe, 2019). This was because there was a wide range of competitive sources of maize, particularly, yellow maize in the world that could be imported to the country provided domestic prices were to be extremely high and beyond reach for smallholder maize farmers, resulting in the country becoming the net importer of maize (Sihlobo, 2016). Figure 2.7 indicates that in 2015 and 2016, South Africa imported 697, 314.97 and 3, 268,718.41 tons of maize, respectively, which accounts for the highest tons imported from 1993 to 2021 (Mokone, 2017; DALRRD, 2020).

2.5 Climate and Agriculture

Agriculture is an important sector in the economy since it provides job possibilities (Baloyi, 2010; DALRRD, 2021), food security, poverty alleviation, and rural development (Mwangi & Kariuki, 2015; Rangoato, 2018). Globally, the industry has a big impact on income redistribution, particularly in underdeveloped nations. Contrastingly, it is also a major contributor to global anthropogenic greenhouse gas (GHG) emissions (Wettstein et al., 2017), accounting for halve of 24% of the global GHG emissions that come directly from agricultural practices such as livestock, soil, and nutrient management (Barrett et al., 2021). Agriculture depends on climate to guarantee crop productivity, profitability, and quality (Resende-Ferreira et al., 2022). Nevertheless, one of the main emerging factors confronting agricultural expansion is climate variability (Rudin, 2022). Climate is defined as long-term weather patterns that describes a region over a period of 30 years (Adedeji et al., 2014; Mazwi, 2019). Whereas climate variability refers to variations in the prevailing state of the climate on all temporal and spatial scales beyond that of an individual weather event (Adedeji et al., 2014; Mazwi, 2019)

Resende-Ferreira *et al.* (2022) asserted that climate extremes like drought, have several effects on crop performance, affecting, for example, the dates of sowing, nutrient management techniques, and ultimately the actual yield obtained. Deforestation and livestock grazing are two agricultural practices that fuel climate change (Mhlanga, 2019). Accordingly, changes in the composition of the global atmosphere and time, as well as the ways in which different regions experience heat waves, droughts, floods, storms, and other extreme weather, are collectively referred to as climate change (Adedeji et al., 2014; Harvey et al., 2022). Furthermore, the prolonged patterns of rising global average temperatures, precipitation and humidity presented by mean values and encompasses variations ion the intensity and occurrence of climate phenomena spanning from months to centuries can be defined as climate change (Thornton et al., 2014; Lineman et al., 2015; Naicker, 2018). Climate change affects agriculture, as outdoor production processes rely heavily on temperature and precipitation levels (Maponya & Mpandeli, 2012; Kephe et al., 2021).

Climate change poses five key hazards to agricultural productivity: precipitation, temperature, carbon dioxide, climatic variability, and fertilizer consumption (Calzadilla et al., 2014). Consequently, agricultural production and activities are affected because climate change altered the prevalence and severity of droughts and floods, insect and disease outbreaks, reduced yields, crop failure, and lastly animal mortality (Lipper et al., 2014; Harvey et al., 2022), and affects agro-ecological conditions such as crop seasons (Grote et al., 2021). Affected climate has a negative impact on agriculture, thus, threatening short rainy season and increasing the prevalence of hunger seasons for example seasonal food insecurities (Muamba & Kraybill, 2010). Interestingly, smallholder farmers in rural areas are reliant on atmospheric conditions such as precipitation, humidity, and temperature (Maponya & Mpandeli, 2012), thus, making production highly sensitive to climate change (Mhlanga, 2019). Undoubtedly, this poses a threat not only to their production, but also food nutrition (Parker et al., 2019). Mpandeli *et al*. (2015) expounded on the heightened susceptibility of smallholder farmers, particularly within South Africa, including the Limpopo Province, to the impacts of climate change and variability. This vulnerability is exacerbated by limited technological adaptations, insufficient educational resources, restricted access to finance and elevated poverty levels. Additionally, Mhlanga (2019) emphasized that a significant proportion of smallholder farmers are classified as poor due to their limited access to financial resources and inputs, rendering them more susceptible to the adverse impacts of climate change, such as lower crop yields and lower income levels.

2.5.1 Climate-smart agriculture

Given that most rural families' livelihoods—particularly those of smallholder farmers—households dependent on rain-fed agriculture faces heightened vulnerability to the risks linked with climate change (Derbile et al., 2016; Derbile et al., 2022). Farmers must come up with creative ways to adapt to climate change since it is gradually changing indigenous agricultural techniques and agricultural produce (Khatri-Chhetri et al., 2017; Senyolo et al., 2021a). Climate-smart agriculture (CSA) is a strategy that integrates adaptation and mitigating the new realities of climate change to constantly achieve food security and nutrition for all people (Lipper et al., 2014; Torquebiau et al., 2018). Considering that smallholder farmers have been using their indigenous and localized knowledge along with their farming activities to manage hazards, this ultimately serves as key solution for farmers that are affected by climate change as it can heighten production and food security by ensuring higher crop yield produced (Mazibuko, 2018).

Mitigation and adaptation strategies have been integrated to demonstrate enhanced socioeconomic and environmental change to livelihoods in poor nations (Naicker, 2018). CSA technologies, like as enhanced maize varieties, generate higher yields under conditions of adequate precipitation and sound soil and pest management methods, yet smallholder farmers often farm in situations where these requirements are rarely satisfied (Sinyolo, 2020). To achieve such, CSA should be the strategy and an approach to attain improved productivity as well as profitability (Duyen-Tran et al., 2019). CSA aims to support resilience, ecological services, value chains, and the sustainability of food systems and landscapes (Matteoli et al., 2020; FAO 2022). It involves a complex set of goals and several transformational shifts, for which there are now identified knowledge gaps about the effectiveness and circumstances of putting CSA alternatives into practice as well as quantifiable results (Torquebiau et al., 2018). According to Kurgat *et al*. (2020), the three goals of CSA are as follows:

i. Develop food systems that are resilient to climate change.
ii. Adapt and build resilient agricultural productivity to support equitable increases in farm incomes, food security, and development; and
iii. Reduce greenhouse gas emissions from agriculture wherever feasible.

CSA technologies integrate both traditional and innovative practices and technologies that are relevant to adapt to climate change and variability, because some of the CSA technologies are improved versions of indigenous practices used in past years (Khatri-Chhetri et al., 2017). For example, using minimum tillage, nutrient management, and residue incorporation improves crop yield, nutrient use, and water while water harvesting, use of improved seeds, ICT based agro-advisories and crop insurances assist farmers to reduce the impact of climate risks (Khatri-Chhetri et al., 2017).

In underdeveloped nations like South Africa, adoption of CSA methods had been slow despite the advantages farmers may get from them (Khatri-Chhetri et al., 2017; Senyolo et al., 2018). Numerous obstacles, including high start-up costs and labour costs, input availability, uncertainty, costs and benefits of technologies, socio-cultural practices, market and credit accessibility, and a lack of knowledge among farmers and extension officers, have hindered the adoption of CSA technologies (Senyolo et al., 2021). The CSA adoption may inadvertently allow farmers to reach a market for their food, generating revenue to meet other human requirements for sustainable livelihoods, such as their children's educational needs, social needs, and health needs (Serote et al., 2021). More importantly, CSA technologies play a significant role in mitigating the factors contributing to harsh climate change events (Sikka et al., 2017). Farmers can utilize various CSA technologies in their farming operations (Duyen Tran et al., 2019). However, their readiness to embrace CSA methods tends to differ because to variances in socioeconomic origins, cultural customs, awareness, and resource endowments among farmers (Duyen Tran et al., 2019). Various CSA practices include crop diversification, which increases resilience, improves soil fertility and control pests and diseases; conservation agriculture and agroforestry, which improve maize yields and adaptation to climate risks (Kurgat et al., 2020), soil, water, and nutrient management such as contour planting, `rainwater harvesting and improved irrigation, which can result in increased infiltration and less soil erosion (Mupangwa et al., 2017).

2.6 Factors Influencing the adoption of Climate-Smart Agriculture

2.6.1 Socioeconomic characteristics of smallholder maize farmers' influencing the willingness to adopt Climate-Smart Agriculture

Various researchers have undertaken the task of studying and identifying the socioeconomic factors that significantly influence farmers' decisions in production. This task, however, is not without its complexities and challenges , as farmers' decisions are shaped by a myriad of social, cultural, and political aspects. The ability of farmers to make informed decisions is intricately linked to the socioeconomic factors that influence these decisions. These factors encompass a wide range of variables, including the farmers' level of education, age, gender, household size, farm size, and income level, among others. The studies conducted by Mwandzingeni *et al*. (2022)

and Muach *et al*. (2021) underscore the essential role of socioeconomic factors in shaping farmers' choice of coping and adaptation strategies to climate change risks.

Understanding the different gender compositions in agriculture allows for examining women's and men's roles, responsibilities, limitations, and opportunities (Sani, 2017). Research investigating the impact of gender on farmers' decisions to adopt CSA shows varied responses influenced by the number of groups in the study area. Mfundo (2013) and Puijwidodo (2016) indicated that elderly female farmers mainly practice smallholder farming in South Africa. However, Kassa *et al*. (2013) contradicted the idea that females dominate the farming sectors, suggesting that males do most farming activities. Males are mostly having a role in decision-making regarding the adoption of CSA as they are considered the head of the house (Mulueta & Amsalu, 2014; Kalu & Mbanasor, 2015; Khoza et al., 2019; Negara et al., 2022; Makamane et al., 2023). However, the study of Serote et al. (2021) argues differently, emphasizing that females dominate the sector, looking at the youth participating in agriculture in the current generation.

The educational level of farmers is a significant socioeconomic factor that contributes to their decision-making. As Dung (2020) highlighted, education correlates positively with adopting CSA and other technological innovations, as it is linked with knowledge. This implies that farmers with a higher level of education are more likely to understand complex agricultural practices and retain information about various ways to improve farming and mitigation methods against climate change, as shown in the studies of Kurgat et al. (2020) and Kifle et al. (2022). The study of Kifle *et al*. (2022) further demonstrates that farmers can be motivated to adopt adaptation and mitigation strategies through education and co-curricular activities. As farmers acquire more education, they are exposed to more information, new technologies, and knowledge, increasing their potential for CSA adoption.

It has been reported that the CSA adoption rate increases with years of farming because it is believed that as smallholder farmers age while practicing production, they learn various activities, including the need for change from traditional practices to modern ways of farming (Ndung'u et al., 2023). Moreover, the study of Negera *et al*. (2022) highlighted that smallholder farmers' agricultural experience positively influences CSA adoption decisions. However, this is conceivable. Through more years in agricultural farming, farmers tend to appreciate the advantages of early adopted methods of CSA and adopt such practices to address climate change risks. The outcome is in line with (Ainembabazi & Mugisha, 2014), which suggested that early in the adoption of agricultural technology, farming expertise matters a lot as it influences the decisions of farmers. However, farmers with more excellent experience prefer modest adoption intensity in the homestead because cropland allows for more yield. As a result, they discourage the adoption of CSA in homesteads due to lower profitability (Ruba et al., 2024).

Farm size is one socioeconomic characteristic of farmers that influences their willingness to adopt CSA. Kalu and Mbanasor (2013) reported that large farm-size owners tend to adopt these CSA practices and become early adopters of such adaptation and mitigation strategies. Additionally, the participation of smallholder farmers in these CSA practices is affected by land pulverization, which makes it challenging to gain from an economic scale, implying that increasing farm size will increase the likelihood of adopting CSA (Lipper et al., 2014).

2.6.2 Smallholder maize farmers' enabling factors influencing the willingness to adopt Climate-Smart Agriculture

Access to extension services positively and significantly affects farmers' adoption decisions. Farmers with access to extension services during the cropping season were likelier to use these technologies than those without (Diallo, 2019). Advisory and extension services provide a developmental goal for smallholder rural farmers. It provides the necessary training to achieve their objective of profit maximization and productivity while maintaining economies of scale (African Development Bank Group (AFDB), 2000). Additionally, farmers can access information on various improved technologies, such as CSA and extension services, as they disseminate information (Mgalama, 2014). Although the adoption of CSA will be improved through the intervention of extension services and advisory services to smallholder farmers (Makate, 2019), it influences the adoption of CSA. Various studies found that it is a significant factor that influences the adoption of CSA practices through the provision of new information and integration of indigenous knowledge of farmers (Abegunde et al., 2020; Ogunyiola et al., 2022; Makamane et al., 2023). The study of Thottadi *et al*.

(2024) recommended that extension services should be developed as a networking system to ensure an effective adoption of CSA among farmers.

Through the adoption of CSA, smallholder farmers will be addressing the CSA policies and achieving sustainable development goals. To transition to climate-smart agriculture, policies must be consistent and support sustainable increases in production and revenue, as well as adaptation and mitigation of climate change (Policy Analysis Network & Governance Project, 2016).

2.7 Methodological literature

2.7.1 Contingent valuation methods

According to Spash (2008), the contingent valuation method (CVM) is an approach by which economists have attempted to place a value on environmental changes. The basic method involves using questionnaires, which seek to ask respondents their willingness to pay (WTP) for an environmental improvement and their willingness to accept or adopt (WTA) compensation for the loss of environmental assets or quality. This method uses survey questions to elicit individuals' preferences for nonmarket goods (Sajise et al., 2021). The essential task of CVM is to design questionnaires that ask respondents for their preferences for certain goods (Davis, 1963; Liu, 2008). It is called CVM because respondents are asked to state their willingness to pay or accept a specific hypothetical scenario created by the researcher (Chiam et al., 2011). The survey created draws on a sample of individuals who are asked to create an imaginary market where they can be able to purchase goods that can be evaluated and, consequently, state their maximum WTP and WTA (Boyer & Moss, 2017). CVM assumes that people understand the market in question and will reveal their preferences in a contingent market that is just as real as a real market (Butterfield & Schwalm, 2016). Despite its limitations, the method has great flexibility, allowing for the valuation of a wider variety of non-market goods and services; hence, it is one of the methods that is currently used and available for estimating non-use values (Rahim, 2008). The CVM studies are carried out through face-to-face interviews, telephone interviews, and mail surveys. In accordance with Rahim (2008), face-to-face interviews are costly and time-consuming; however, they are the best because non-response bias can be reduced.

Conceptual framework

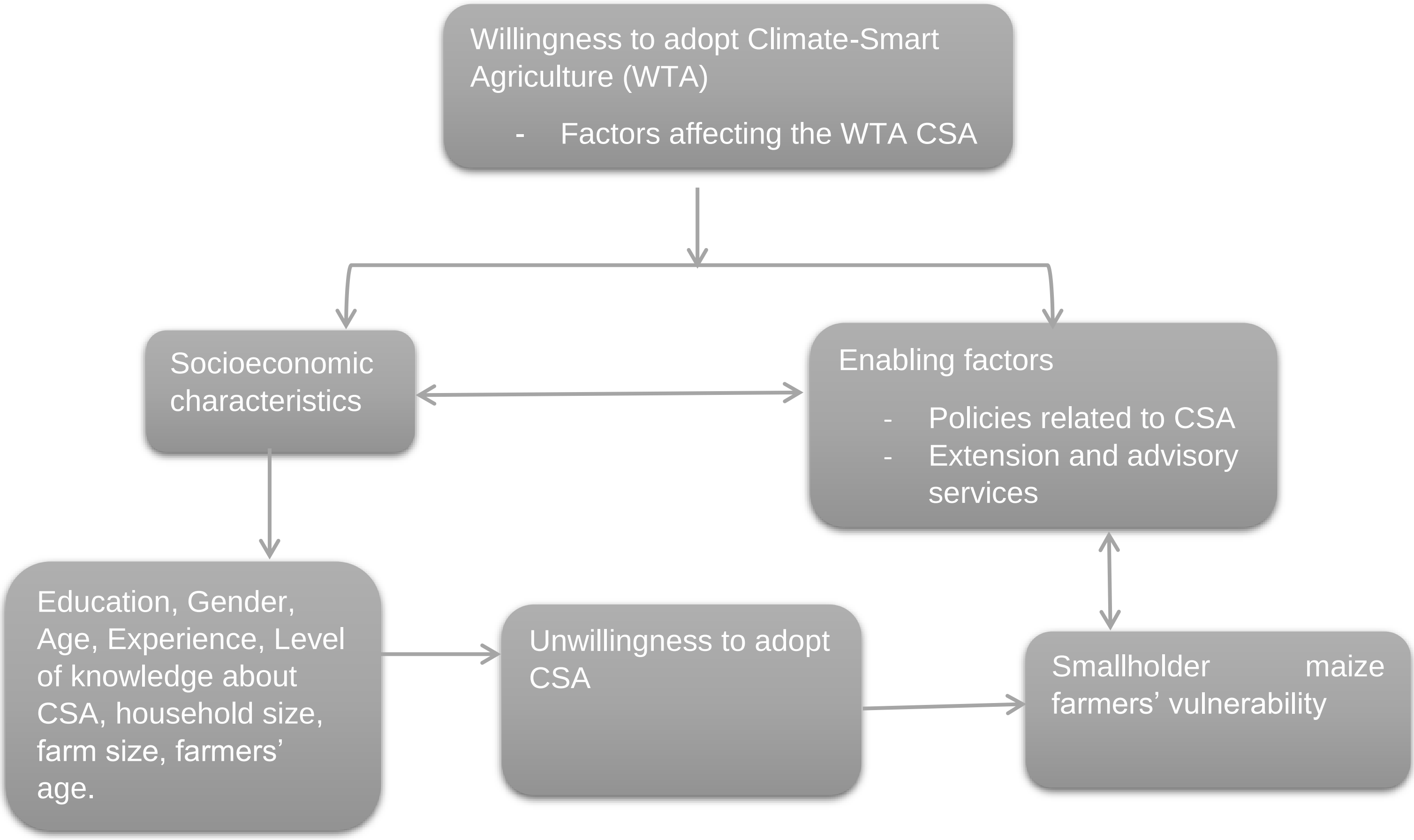

Figure 2.8: Conceptual framework for smallholder maize farmers' willingness to adopt climate-smart agriculture (CSA) and factors affecting the adoption of CSA practices. Source: Authors' compilation (2024).

Figure 2.8 above presents the conceptual framework indicating smallholder maize farmers' decision to adopt CSA practices; however, their decision is mainly affected by socioeconomic characteristics, policies related to CSA, and extension and advisory services. Socioeconomic factors that can influence the willingness to adopt CSA positively and negatively. Factors such as education, experience, farm size, and level of knowledge can positively influence the willingness to adopt because they significantly impact farmers' decision-making process. Education provides farmers with the necessary skills to comprehend and make rational decisions concerning their adoption of improved adaptation strategies to address the risks posed by climate change. Advisory and extension services play a vital role in disseminating information and thus enable farmers to learn more about the benefits of adopting CSA practices.

Extension officers assist and disseminate new information that can be retained to cope with the effects of climate change.

Moreover, policies related to CSA will ensure that farmers' needs are met through the provision of workshops to enhance farmers' knowledge. This will influence the willingness to adopt to adopt. However, factors also influence the decision to adopt negatively, such as age, gender, and level of income. Older farmers are more reluctant to adopt these CSA practices than younger farmers. The unwillingness to adopt policies related to CSA can increase farmers' vulnerability to climate change risks.

2.6 Chapter overview

The literature reviewed maize as an adoptable multipurpose crop since it is used for a variety of things. The crop played a vital role in food systems and food security as it served as both food and animal feeds. Agriculture remains vulnerable to climate change as it rainfed sector, subjecting maize to the vulnerability of being exposed to climate change risks. Findings of existing literature reviewed indicated that climate change has an impact on the South African economy in many aspects. Maize as a traditional crop that is consumed mainly by households in rural areas is highly vulnerable to pest damage, extreme weather conditions and lack of rainfall.

Agricultural production is affected by climate change as it altered pests and disease outputs, increase in severity of droughts and floods, poor yields, and livestock mortality. Additionally, the impact of climate change can be mitigated through adoption of CSA. Although, literature indicated that South Africa had lower adoption rates of CSA, farmers should be encouraged to adopt such practices to mitigate and adapt against risks posed by climate change. It is imperative as in line with the aim of the study which was to examine the vulnerability of farmers and their willingness to adopt CSA as a strategy to curb the effects of climate change. The study will provide in-depth knowledge and information to farmers about various improved mitigation and adaptation strategies to improve their productivity, profitability, and quality of produce.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

Research methods/methodology is an approach that group together the study's techniques to make rational and meaningful purpose on how the researcher is going to conduct the study. Therefore, research methodology provides a plan on how the study will answer research questions or achieve research objectives. For these reasons, this chapter gives details about the study area, research design, data collection methods and more information about the analytical techniques that were employed to address the research objectives.

3.2 Description of study area

The study was conducted at three selected areas: Ga-Makanye in Polokwane Municipality, Gabaza in the Tzaneen Municipality and Giyani in Giyani Municipality in the Limpopo Province. The study was conducted in three selected areas: Ga-Makanye in Polokwane Municipality, Gabaza in Greater Tzaneen Local Municipality, and Gabaza in Greater Giyani Municipality in Limpopo Province, South Africa. Ga-Makanye is a small village situated outside Polokwane, and it has a total population of 9536 and 2256 households (StatsSA, 2022) However, the study chose 37 farmers as these were the only available maize farmers in the areas due toothers relocating to urban areas for better job employment. It is dominated by black and Sepedi-speaking individuals. Gabaza is also a small village outside Tzaneen town dominated by black people, mainly consisting of different tribes. It consists of 2413 total population with 671 households. The area is dominated by Xitsonga-speaking individuals constituting 78% of the population. Giyani is a town situated in the eastern part of the province featuring 25954 total population with 8096 households; it is dominated by the Xitsonga tribe (StatsSA, 2022).

Figure 3.1: South African map showing five districts in Limpopo Province: Author's compilation (2024)

The study chose these three areas due to their location in different agroecological zones (Kangogo et al., 2021 & Kephe et al., 2020). Ga-Makanye is characterized by a humid subtropical climate that threatens the monsoon winds (seasonal winds). The area experiences arid winters and very hot summer days. Likewise, Gabaza is suited within Tzaneen and experiences monsoons; thus, it is classified as a humid subtropical climate. There are hot and humid summers with frequent rainfall, unlike in Ga-Makanye, and dry winters, which are hot. Giyani experiences different and unique climatic conditions. It is a subtropical climatic zone characterized by hot and dry summer and winter days. The area can reach a peak temperature of 43 degrees Celsius, which is extremely hot. This harsh temperature results in heat waves heatwaves even during winter, and the area experiences harsh temperatures; this shows the need for farmers' vulnerability assessment and the adoption of CSA.

3.3 Research design

The research utilised multipurpose (mixed method) research design, to integrates both qualitative and quantitative methodologies. Mixed-method research design is helpful because it does not only afford integration of quantitative and qualitative methodologies, but also provides an opportunity to validate the results of quantitative descriptive statistics and econometric model with qualitative data (Kumar, 2011; Derbile et al., 2022). Furthermore, the mixed method research design allows researchers to use the strength of one data to mitigate the weaknesses of the other data (George, 2022). The study used mixed method because smallholder farmers' vulnerability assessment is quantitative in nature as it requires discrete values to measure exposure, sensitivity, and adaptive capacity while willingness to adopt is qualitative in nature. Measures of dispersion (descriptive statistics), Vulnerability index assessment, Double-hurdle model, and willingness to adopt through Contingent valuation method were used to the address research objectives, 1, 2, and 3, respectively.

3.4 Sampling method(s) and sample size

The study employed a multistage sampling technique combining both non-probability and probability sampling techniques. In the first stage, the Limpopo Province was purposefully selected as the main area because of the prevalence of smallholder rural maize farming, which contributes to food security within the province and country. Secondly, two districts were purposefully selected, Capricorn (dry sub-humid) and Mopani (semi-arid) due to their different agro-ecological climate zones. Thirdly, Ga-Makanye village was purposefully selected from the Capricorn District in the Polokwane Municipality, and two areas, Gabaza and Giyani Municipality, were purposefully selected from Mopani Municipality. Because researchers were unfamiliar with the study region and there was not a large maize farmers' population, households we used as a proxy because most rural households in South Africa grow maize for consumption and income generation. Subsequently, the study used a 209-sample size of maize farmers that were selected randomly and proportionate to household' sizes in each village. The study used Yamane's formula to select the sample size for each area.

Yamane's formula (Yamane, 1967) was used for smallholder maize farm household sample selection in the selected study areas, which is given below as:

$$n = \frac{N}{1 + N(e)^2}$$

There was no population for smallholder rural maize farmers', the study has used number of households as a proxy for sampling frame for sample size.

Makanye (n)= $\frac{39}{1+39\left(\frac{10}{100}\right)^2} = 28$, Gabaza (n)= $\frac{671}{1+671\left(\frac{10}{100}\right)^2} = 87$ Giyani (n)= $\frac{8098}{1+8098\left(\frac{10}{100}\right)^2} =$ 98

However, departments have information on smallholder farmers' population with land sizes of about 20-500 hectares that can be accessible through extension officers (Mathithibane, 2021). Mathithibane's study definition for smallholder farmers' is different for this study because smallholder farmers in this study are rural subsistence farmers with farm size less than 2 hectares. FAO (2015) mentioned that smallholder farmers in South Africa typically have larger average land sizes compared to rest of Africa, where farm sizes are generally less than 2 hectares, in South Africa this was considered as subsistence, however, FAO do not have information on rural subsistence farmers.

3.5 Data collection

The study used primary cross-sectional data. The data were collected using both qualitative and quantitative methods to understand farmers' willingness to adopts and factors influencing adoption of CSA (Senyolo et al., 2021a; Mpandeli & Maponya, 2013). The study used structured questionnaires, focused group discussions (FGDs) and Likert scale to collect data from the respondents. The collected data were used to describe socioeconomic characteristics of maize farmers' as well as factors such as age, educational level, gender, household size, farm size and agricultural experience as well as factors influencing willingness to adopt (WTA) to adopt CSA. The multicollinearity test was conducted using latest IBM SPSS 29.0 packaged system using the variance inflator factor (VIF). The VIF analyse the total effect of each independent variable against all set of independent variables, which is known as multicollinearity.

3.5.1 Model Specification

The study used two methods or approaches for the farmers' vulnerability indicator selection, and this include deductive and inductive approaches. According to Adger *et* *al*. (2015), the deductive approach is based on theoretical understating of the relationships derived from the theory while the inductive uses statistical methods to draw relationships of the indicators on many regressors. The study divided the indicators based on the two approaches such as including socioeconomic and biophysical factors to assess the sensitivity, exposure, and adaptive captive of climate risk to maize farmers. The study used the following steps to choose the farmers' vulnerability index, it was based on the following formula $\frac{(X_{ij}-\overline{X}_i)}{S_{d1}}$ ………..(1)

Whereby X_{ij} is the value of the indicator, $\overline{X}_i$ is average value of the indicators across the respondents and Sd_i is the standard deviation.

Table 3.1: Components of farm vulnerability indicators

Determinant of vulnerability	Component indicator	Indicator Description	Unit of measurement
Exposure	Extreme weather events such as floods, drought, frost, fire (changes in climate)	The frequency of occurrence of the exposure to vulnerability	Number of occurrence e.g number of drought/frosts and rainfall events
Sensitivity	Percentage in irrigated land, crop diversification, livestock mortality	Severity and percentage of impacts of climate change risks.	Percentage
Adaptive capacity	Farm income, household size, access to extension services, farm holding size	Ability of the maize smallholder farmers to adapt or cope to hazards or impacts	Rand, Number of households, hectares Number of extension workers

Vulnerability = (Sensitivity + Exposure) + Adaptive capacity …………………… (2)

The Formula for farmers' vulnerability is adopted and indicated in the above equation (Moret, 2014). Smallholder maize farmers were used as respondent on the vulnerability assessment being the subject of the study (Y), with Xn referring to the elements of vulnerability indicators (exposure, sensitivity, and adaptive capacity). Therefore, sensitivity and exposure are written together in brackets due to the role played in terms of shaping the overall vulnerability, implying that when a farmer is exposed to climate change risks, he will as well be sensitive to these risks. The values of X and Y were obtained from the mean value and standard deviation in equation 1.

$$\frac{X_{ij}}{Y_{ij}} = (x_{11} + x_{12} + \ldots\ldots + x_{2n}) - (y_{11} + y_{12} + \ldots\ldots\ldots + y_{2n}) \quad \ldots\ldots\ldots\ldots (3)$$

Whereby: i was the number of smallholder maize farmers' (response, j is the number of columns (n=19 variables of vulnerability indicators)

The vulnerability index is given as follows:

$$\text{FVI} = \sum_{i=1}^{n} \left(\frac{X_{ij}}{Y_{ij}} = (x_{11} + x_{12} + \ldots\ldots + x_{2n}) - (y_{11} + y_{12} + \ldots\ldots\ldots + y_{2n})\right) \ldots\ldots\ldots (4)$$

The above equation was used to calculate the direction of the relationship of the indicators. This gives rise to the Ordinary least squares equation for the variables. It is as follows.

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots\ldots\ldots\ldots + B_kX_k + \in \ldots\ldots\ldots\ldots (5)$$

$$WTAi * = B_0 + B_1FS + B_2EL + B_3GND + B_4AG + B_5AE + B_6HS + B_7ID + B_8CD + B_9AES + B_{10}ICSA + B_{11}E + B_{12}S + B_{13}IS + B_{14}CM + \in \ldots\ldots\ldots\ldots (6)$$

$$WTA_i^* = \begin{Bmatrix} 1 \; if \; WTAi * > 0 \\ 1 \; if \; WTAi * < 0 \end{Bmatrix}$$

3.6 Analytical techniques

3.6.1 Measures of dispersion

Measures of dispersion (descriptive statistics) were employed in the study to offer a summary of the sample and its measures. Specifically, measures of dispersion were used to analyse central tendencies (such as the expected mean value, median and mode) to achieve the first objective: describing socioeconomic characteristics of maize farmers for farm assessment in Limpopo Province at three selected municipalities.

3.6.2 Farmers' vulnerability assessment

In this study, farmers' vulnerability assessment was used to analyse the vulnerability indicators; "sensitivity, exposure, and adaptive capacity" through an organized focused group discussion (FGDs) of 5 farmers per group and 10 farmers in a larger available number of farmers. The study assisted the respondent in selecting indicators that are needed using the vulnerability assessment guidelines provided by the research in the questionnaire. The study used three vulnerability indicators namely, sensitivity, exposure, and adaptive capacity. Furthermore, 19 variables were selected to calculate the farmers' vulnerability index, and includes farmers' house damaged, productive land damaged, roads affected, droughts, extreme temperatures, strong winds, crop diseases, availability of water, and adaptive capacity to CSA practices such as crop rotation, crop diversification, rainwater harvesting, site-specific nutrient management etc. arm vulnerability was ranked from 0 (least vulnerable) to 1 (most vulnerable) in the study using the livelihood vulnerability index. Indexes and indicators varied from 0 to 1, indicating extremely low to very high vulnerability, according to Dobkowitz *et al*. (2020). Here is a description of the indices: According to the FaVI rating index, there are five levels of vulnerability: very low (0–0, 19), low (0–0, 39), moderate (0–0, 59), high (0–0, 79), and very high (0–0, 81).

3.6.3 Double-hurdle model and Contingent valuation method (CVM)

The study used the Double-hurdle model on the presumption that CSA adoption willingness involves two separate judgments (Diendere, 2019). According to Cragg (1971), Double-hurdle model implies that smallholder farmers would make two consecutive decisions on whether to adopt CSA (Diendere, 2019; Hitayezu et al., 2017). Equations 6 and 7 reflect the first hurdle, the CSA adoption (Yes/No) factor, which was estimated using a Probit model.

A truncated count distribution model was used in the second hurdle to find factors that affect adoption willingness. The model used is as follows:

$p^*i = C^*{}_i\alpha + \varepsilon i$ (Adoption decision) ……………………………………………………………………………………………7

$p_i = 1$ if $p^*{}_i > 0$ and 0 if $p^*{}_i < 0$……………………………………………………………8

$WTACSA = X'_i\beta + u_i$ (Factors affecting the level of adoption) ……………………………………………………………………………………...9

$y_i = x'_i + u_i$ if $y*_i > 0$ and $y^*_i > 0$……………………………………………………………………10

Whereby,

- "p^*_i is considered the variable that explains the decision to adopt CSA by smallholder maize farmers;
- p_i is the variable that is observed adoption decision and takes the value of 1 if the smallholder farmer is willing to adopt at least three CSA practices; it is 0 if otherwise.
- $WTACSA$ is a dormant variable used to describe the decision on factors affecting the adoption.
- y_i is observable variable of adoption measured as the number of CSA practices to level of adoption.
- C and X gives the direction for independent variables for the decision to adopt
- α and β are the parameters to be estimated (Roco et al., 2014).

In the Double-Hurdle model, the regression analysis of the probability to adopt CSA is estimated using a truncated regression procedure given by the following equation (Hitayezu et al., 2017)

$$P(WTACSA > 0) = \Phi(C^*_i\alpha)\Phi(\frac{x_i\beta}{\sigma}) \quad \text{……………………………………………………11}$$

$$E(WTACSA > 0) = \Phi\left(\frac{x_i\beta}{\sigma}\right)^{-1} \quad \text{…………………………………………………………12}$$

3.6.4 Contingent Valuation Method

Contingent valuation is a method used to gauge the perceived value individuals place on a particular commodity by asking them if they would be willing to accept or pay for the good (Holvad, 1999). Smallholder maize farmers in the study area were asked to place or state their preference on the CSA by selecting at least three CSA practices they are most likely to adopt, given the opportunity, and by indicating which CSA practices they prefer to adopt to address climate change risks. The CSA practices considered include crop insurance, rainwater harvesting, drought-tolerant maize seeds, crop rotation, crop diversification, site-specific nutrient management, conservation agriculture, and others. Through structured questionnaires and Likert scales, the contingent valuation method was used to assist farmers in at least choosing three CSA practices to indicate their willingness to adopt CSA given the opportunity. When a farmer chose less than three, it indicated that they were unwilling to adopt CSA (the minimum of three indicated the willingness to adopt). Farmers were also grouped in FGDs to participate in choosing an effective strategy; however, there was a lack of awareness about CSA and what CSA is about, as it was never promoted or implemented within the study areas. This clearly shows that a lack of information and awareness about CSA contributes significantly to obstacles that limit the effective adoption of CSA in Ga-Makanye, Gabaza, and Giyani. A summary of explanatory variables is provided in the table below (see Table 3.2).

Table 3.2: List of variables considered in the study.

Variable	**Description**	**Unit of measurement**
Dependent variable		
Smallholder maize farmers' willingness to adopt CSA (Y)	1 if smallholder farmer is willing to adopt CSA and 0 otherwise	Dummy variable
Independent variables		
X_1 – Farm size (FS)	Size of the farm	Hectares
X_2 – Educational level (EL)	Number of years spend in school	Years
X_3- Gender (GND)	1= if the respondent is the female 0 = otherwise	Dummy variable
X_4- Age (AG)	Age of a respondent	Years
$X_{5\text{-}}$ Agricultural experience (AE)	Number of years in farming	Years
X_6- Household size (HS)	Number of household members	Number
$X_{7\text{-}}$ Income diversification (ID)	1= Yes if the respondent diversifies their income 0 = otherwise	Dummy Variable
$X_{8\text{-}}$ Crop diversification (CD)	1 = Yes if the respondent diversifies their crop 0 = otherwise	Dummy variable
$X_{9\text{-}}$ Access to extension services (AES)	1 = Yes if the respondent has access to extension services 0 = otherwise	Dummy variable
X_{10}- Information about CSA (ICSA)	1 = Yes if respondent has information about CSA 0 = otherwise	Dummy variable
X_{11}- Exposure of the farmer to climate risk (E)	1= If the respondent is exposed to climate risk 0 = Not exposed	Dummy variable
X_{12}- Sensitivity of farmer resources to climate risk (S)	1= If the respondent is sensitive to climate risk 0 = Not sensitive	Dummy variable

X_{13}- Insurance (IS)	1 = Yes if the respondent has insurance 0 = Otherwise	Dummy variable
X_{14}- Cooperative membership (CM)	1= Yes if the respondent has cooperative membership 0= Otherwise	Dummy variable

3.7 Limitations of the study

The study was conducted at three different places, which experience different climatic conditions and consist of different languages spoken. This was likely to pose the challenge of language barrier between researchers and participants, particularly because most of the households in Giyani and Gabaza speak mainly Xitsonga and acquire little understanding about the language spoken by the researchers. To address this challenge and ensure data collection run smoothly, the researcher sought support from the trained enumerators and other interpreters working as Assistant Agricultural Practitioners (APP) from the Department of Agriculture, Land Reform and Rural Development. Despite the study's anticipated minimum sample size being 213, only 2019 smallholder farmers were interviewed. The initial number of farmers were not satisfied because the data was collected during the week which had an impact on availability of farmers in their households and respective plots. The conduction was done with the help of extension officers and department's contract workers. There was a language barrier and due to the number of translators, some farmers were not interested in participating.

3.8 Chapter overview

This section provided an extensive overview of the research methodologies utilized for the study, covering aspects such as the study area, research design, data sampling methods, an outline of the methods and instruments used to acquire data from the identified participants and analyzed it. It also presented a thorough examination of the methods applied to achieve the study objectives, including the use of Measures of dispersion for profiling socioeconomic characteristics, the assessment of farmers' vulnerability using exposure, sensitivity, and adaptive capacity indexes, and the analysis of factors influencing the adoption of climate-smart agriculture among smallholder farmers in Ga-Makanye, Gabaza and Giyani in Limpopo Province to adopt climate-smart agriculture. To restate methods chosen for this study, The chapter further highlighted that a non-probability sampling procedure (i.e. Snowball purposive sampling methods) was employed in selecting the respondents for the study. Finally, Contingent Valuation Method and Double-Hurdle Model was used to address the willingness to adopt CSA. The table of variables used to draw questions for the survey that was employed to interview farmers together with their measurements were also presented in a tabular form in this chapter. The next chapter presents the statistical description of the smallholder maize farmers sampled in Ga-Makanye, Gabaza, and Giyani in Limpopo Province as well as the presentation of the econometric results and their discussion.

CHAPTER 4: DESCRIPTIVE RESULTS AND DISCUSSION

4.1 Introduction

This chapter provides results from analysis of various analytical techniques and discusses those results in relation to the literature. Both Descriptive and Econometric results are presented together with the discussion of how they relate with the literature. Over the course of a month in July 2023, 209 smallholder maize farmers provided the data utilized in this investigation. This chapter presents descriptive statistics like bar and pie charts, percentages, and frequencies, mean values, and chi-square values.. The vulnerability results are in the form of vulnerability indicators, sensitivity, exposure, and adaptive capacity along with farmers' vulnerability index.

4.2 Smallholder maize farmers' willingness to adopt CSA in Ga-Makanye, Gabaza, and Giyani

4.2.1 Ga-Makanye smallholder maize farmers' willingness to adopt CSA

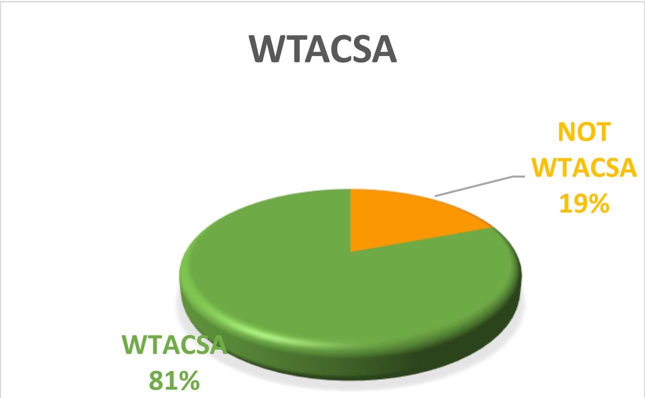

Figure 4.1: Sampled smallholder maize farmers decision to adopt CSA in Ga-Makanye (n= 26)

Source: Author compilation from survey data, 2023.

A larger proportion of 81% (22) smallholder maize farmers from the total of 26 sampled farmers in Ga-Makanye depicted in the Figure 4.1, indicated willingness to adopt climate-smart agriculture. These findings imply that smallholder farmers value their production of maize as it serves as the source of consumption and income, hence the will to adopt CSA to address climate change-related risks. Farmers have indicated that, they are committed to adopt the improved agricultural practices to advance and increase their yields. Most of the farmers specified that they are willing to adopt CSA because maize is consumed daily as maize meal (pap).

Conversely, a smaller number of sampled maize farmers, comprising 19% (5 individuals), expressed unwillingness to adopt CSA practices. Their rationale for this decision was that their age is limiting their ability and capability to adopt the new practices and information. On that account, such farmers noted that they mostly rely on indigenous knowledge gained from their grandparents. Farmers believed that due to less educational knowledge and access to extension services, they will not be able to learn these CSA practices. Their view was however, that if they do access extension officers more frequently, they can encourage their grandchildren to attend meetings to extend the agricultural knowledge.

4.2.2 Gabaza smallholder maize farmers' willingness to adopt CSA

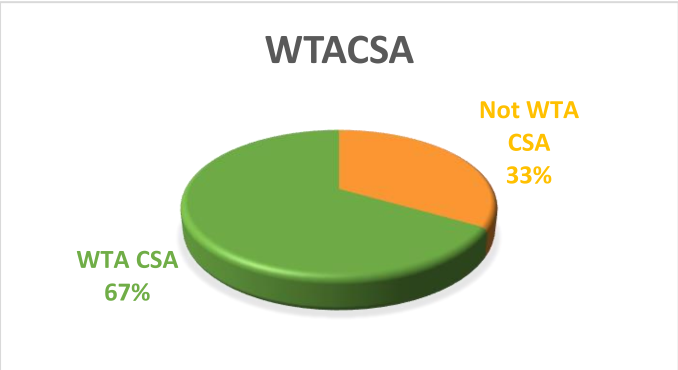

Figure 4.2: Sampled smallholder maize farmers' decision to adopt climate-smart agriculture in Gabaza (n= 87)

Source: Author compilation from survey data, 2023.

A sizeable portion of smallholder maize farmers in Gabaza, about 67% (58) sampled, were found to be inclined towards willingness to adopt CSA, as illustrated in the Figure 4.2. This indicates that these farmers attach importance of their maize production, for household consumption. They frequently trade their maize harvest for a processed maize meal at local processing companies. These findings align with Khumalo *et al.* (2011) observation that in rural areas, many households and smallholder farmers continue to cultivate white maize for milling at nearby village-based hammer mills, often in exchange for a fee (Traub & Jayne, 2014). These smallholder farmers treat their produce as cash crops, which can be sold to local millers/processors or the community. However, farmers who sell their maize at the community have indicated that selling maize at the community level is profitable as compared to local millers. According to Sautier *et al*. (2006), at the community level, grain prices are agreed upon between the sellers (i.e. farmers) and buyers. The willingness to adopt these practices will improve soil nutrients and results in less wilting point on the crop, consequently, improve production.

Conversely, a smaller group of smallholder maize farmers, comprising 33% (29) of the sampled participants, showed reluctance towards adopting CSA. Their reasons for not willing to adopt are linked to their age, which they believe hinders their ability to adopt new practices and information. Due to their limited access to education and extension services, they typically depend on traditional wisdom (Indigenous knowledge) transformed from their grandparents. These farmers feel that learning the practices associated with CSA might be challenging for them, but they remain open to the possibility of considering CSA provided that certain conditions are met such as workshops conducted in their native language, more demonstration used than writings and allowing their grandchildren to attend for farmers who cannot read or write.

4.2.3 Giyani smallholder maize farmers' willingness to adopt CSA

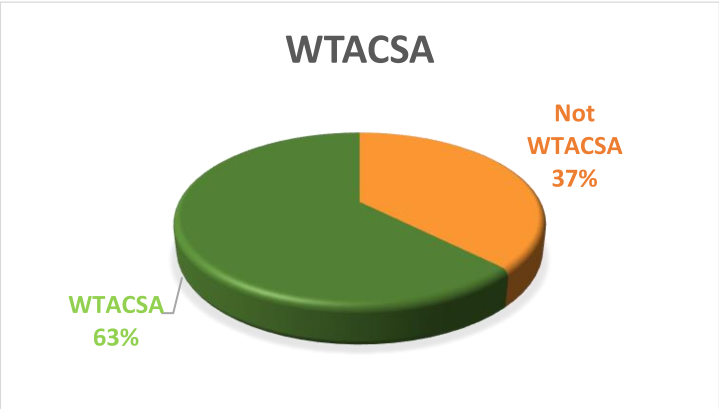

Figure 4.3: Sampled smallholder maize farmers' decision to adopt climate-smart agriculture practices in Giyani (n=96)

Source: Author compilation from survey data, 2023.

Many smallholder maize farmers in Giyani of about 63% (60) sampled, were found to be inclined towards willingness to adopt CSA, as illustrated in the Figure 4.3. This suggests that these farmers place a value on their maize production, willing to adopt improved agricultural practices. These farmers who were willing to adopt have indicated that they are willing to adopt CSA because they rely on consumption of maize to sustain their households. They also often exchange their maize harvest for maize meal at nearby processing firms. These farmers express a commitment to adopting improved agricultural techniques to enhance their productivity. Many of them are enthusiastic about CSA due to their culture and traditional reliance on maize for sustenance and family support.

However, a lower percentage of smallholder maize farmers—that is, 33% (36) of the studied participants—exhibited reluctance in making the decision to adopt CSA. There are several reasons that farmers have indicated as to why they are not willing to adopt CSA. Their reasons include that, they produce on a larger scale of land, hence, these practices will be costly and require capital intensive, require more time and adequate understanding. They also mentioned that lack of government support through provision of inputs such as seeds, water, fertilizers, and self-development programmes also hinder their will to adopt CSA.

4.3 Gender distribution of sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani

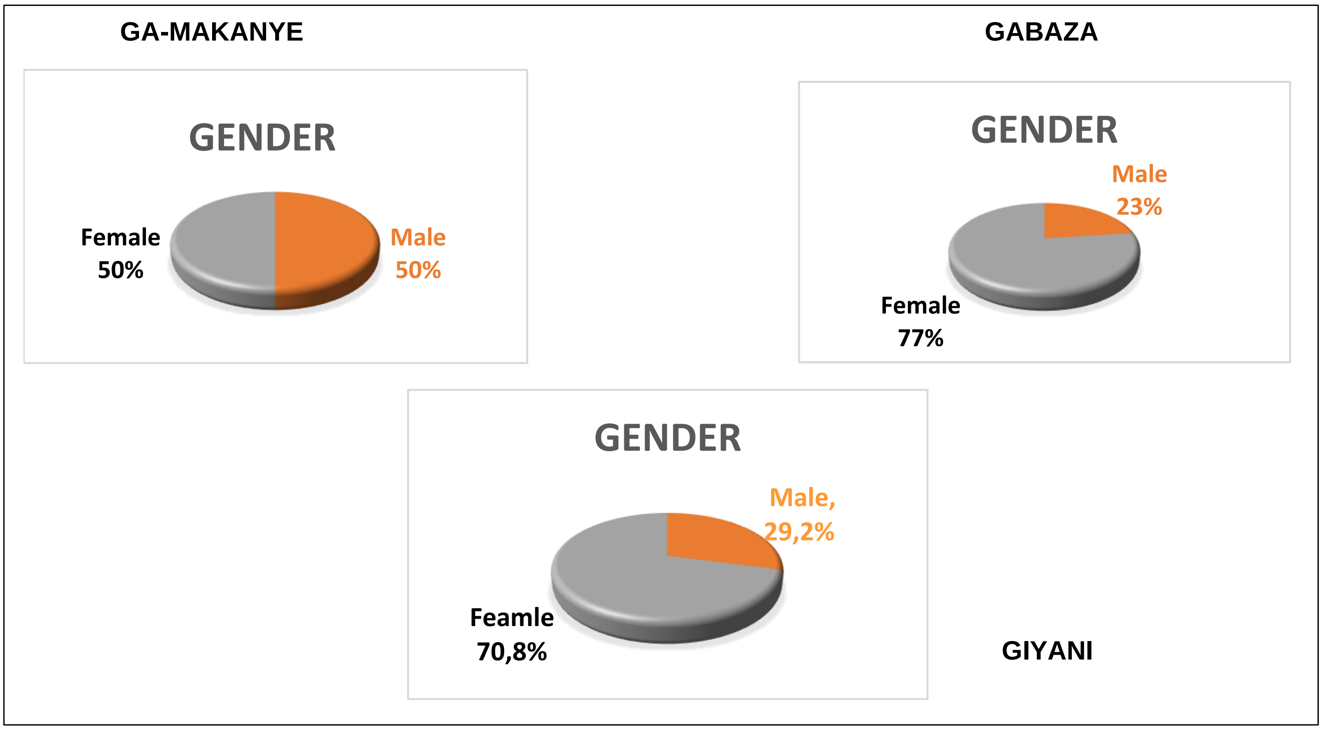

Figure 4.4: Sampled smallholder maize farmers' gender in Ga-Makanye, Gabaza, and Giyani

Source: Author compilation from survey data, 2023.

In Ga-Makanye, 50% of the interviewed respondents among the sampled smallholder maize farmers (n=26) were farmers who were both male and female, as shown in Figure 4.4. In the meantime, women farmers made up a majority of those questioned in Gabaza among the sampled smallholder maize farmers (n=87). However, there were only 20 male farmers. This indicates that among the survey's female and male maize growers, the gender distribution is 77% and 23%, respectively. This could mean that there are more female-headed households in the area since the men have moved to nearby cities in search of higher living conditions. Most of the families in the community that farm livestock are headed by men. The research findings reveal that a considerable proportion of smallholder maize farmers (n=96) interviewed in Giyani were female, as illustrated in Figure 4.4. In contrast, there were fewer male farmers, with women constituting a higher percentage of respondents, 70, 8% (68), while men comprised a smaller proportion 29, 2% (28). This distribution suggests that approximately 70, 8% of surveyed maize farers were female, and 29, 2% were male. This discrepancy could imply the presence of female-headed households, with males potentially not engaged in agriculture or any other industry. Additionally, most female farmers in the research area were widows, contributing to this pattern. These results seem to be contradicting with studies of Kassa *et al*. 2013) that stated that in South Africa small scale faring is mainly practised by males as compared to females. However, the study is in line with studies of Mfundo (2014) that showed that South African small-scale farming is mainly dominated by female farmers practising more backyard farming, while males are active in other economic activities.

4.4 Educational level of the sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani

The educational level of smallholder maize farmers is a significant factor influencing their willingness to adopt CSA practices, as it impacts their risk management, preparedness and understanding of improved agricultural techniques such as drought-tolerant maize seeds (Tang et al., 2021). Moreover, a farmers' education level serves as a measure of their capability to comprehend various CSA practices. The data in

Figure 4.4 depicts the educational backgrounds of the smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani who participated in the study (n=209)

4.4.1 Educational level of the sampled smallholder maize farmers in Ga-Makanye

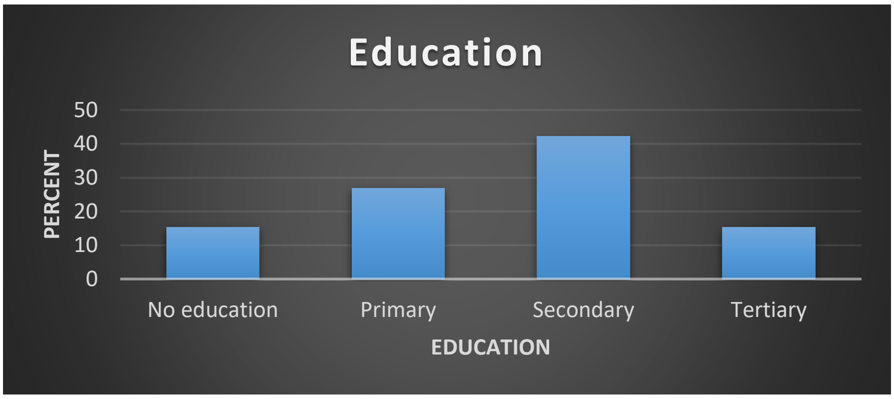

Figure 4.5 Sampled level of education for Ga-Makanye smallholder maize farmers

Source: Author compilation from survey data, 2023.

The findings in Figure 4.5 reveal that most (42, 3%) and about (26, 9%) of the smallholder maize farmers within Ga-Makanye village have obtained secondary and primary education, respectively. The percentage for smallholder maize farmers who matriculated and furthered their studies to the tertiary level were about 15, 4% (4). About 15, 4% never attended school. The results indicate that, significantly farmers had obtained some form of education and will positively adopt the CSA.

4.4.2 Educational level of the sampled smallholder maize farmers in Gabaza

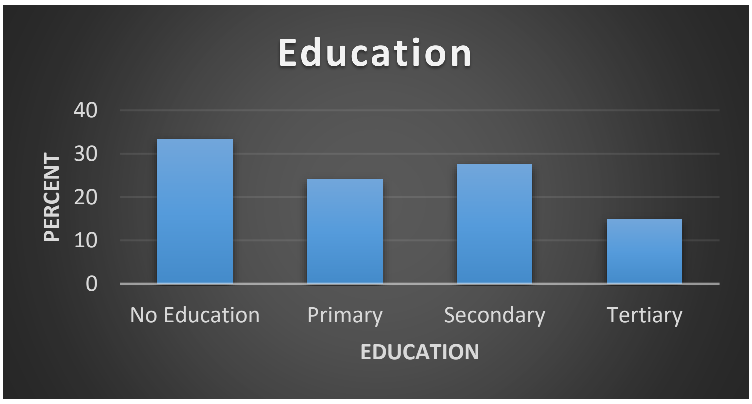

Figure 4.6: Sampled level of education for Gabaza smallholder maize farmers

Source: Author compilation from survey data, 2023.

The results in Figure 4.6 show that majority 33, 3% of the smallholder maize farmers in Gabaza (n=87) from the total sampled in the village did not receive any form of formal education. Furthermore, about 27, 6% (24) had secondary education but did not complete high, some of them had completed high school but did not pursue further education. The percentage of maize farmers who possessed only primary education and accounted for about 24, 1% (21). Individuals who finished high school and pursued higher education at the tertiary level constituted 14, 9% (14) of the interviewed farmers. A considerable portion of smallholder maize farmers in the research area did not have formal education. This suggests that they are less likely to be open to adopting CSA to grasp the information and knowledge associated with CSA. These shows indicate that there are more uneducated farmers in the study area. This should indicate the need for major intervention because education is believed to improve an individual reasoning, knowledge retention, and increase awareness of variable technologies that can be adopted (Murithi et al., 2021).

4.4.3 Educational level of the sampled smallholder maize farmers in Giyani

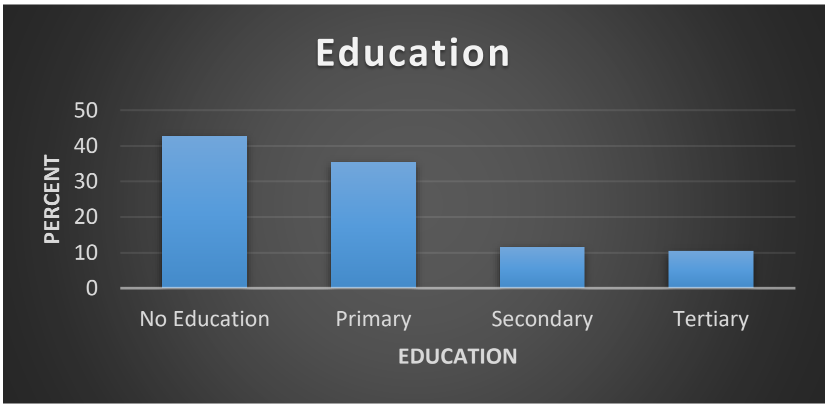

Figure 4.7 Sampled level of education for Gabaza smallholder maize farmers

Source: Author compilation from survey data, 2023.

According to Figure 4.7's data, the majority (42, 7%) of Giyani's smallholder maize farmers (n=96) out of all those sampled in the village did not complete any kind of formal schooling. This implies that most farmers in the village lack literacy skills and are unable to read or write. In contrast, just 35, 4% of farmers did not complete their primary education, compared to those who did not attend school (34). This further emphasises that most smallholder maize farmers in the area will not comprehend information about CSA as they do not have necessary skills and capabilities to read and write. Moreover, farmers who acquired their formal education and have matriculated accounted for about 11, 5% while those who furthered their studies in the tertiary level were 10, 4% (10). This imply that although some smallholder farmers possess formal education, the area is dominated by people who did not go to school, as a result, it may hinder the development of place in terms of adopting new innovative technologies.

4.5 Income diversification of the sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani

4.5.1 Income diversification of the sampled smallholder maize farmers in Ga-Makanye

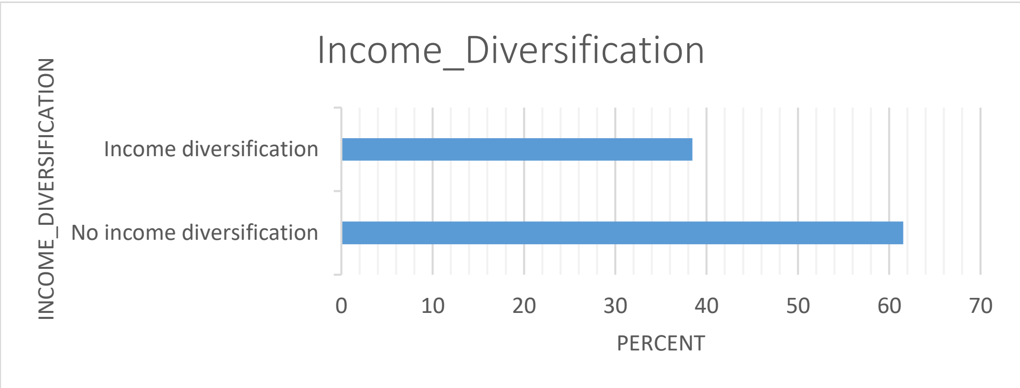

Figure 4.8 Sampled smallholder maize farmers' decision on income diversification in Ga-Makanye

Source: Author compilation from survey data, 2023.

The results presented in Figure 4.8 indicate smallholder maize farmers' decision to diversify their income in Ga-Makanye Village. The results show that a very few (38, 5%) farmers were diversifying their level of income by using their personal income to invest more in various agricultural practices and crops. On the other hand, more farmers (61, 5%) were not diversifying their incomes. One of the reasons that farmers have indicated is that they mostly rely on government support in terms of social grants, and thus, the money is only limited to household decisions.

4.5.2 Income diversification of the sampled smallholder maize farmers in Gabaza

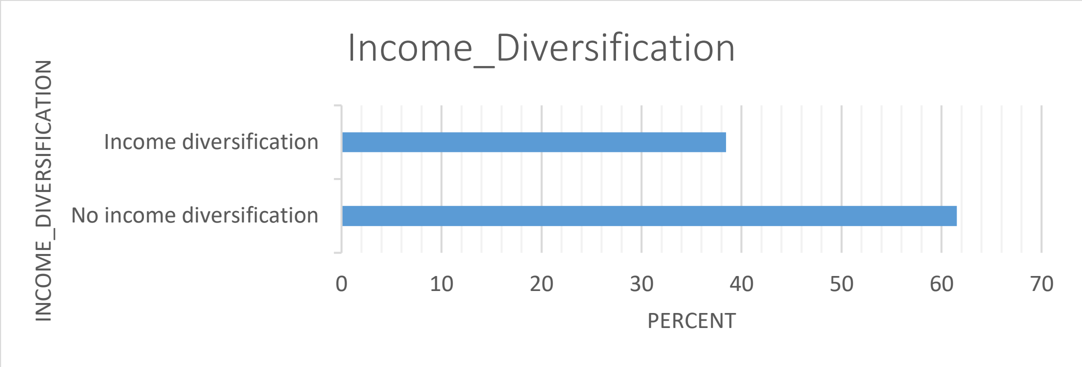

Figure 4.9: Sampled smallholder maize farmers' decision on income diversification in Gabaza.

Source: Author compilation from survey data, 2023.

Figure 4.9 depicts the outcomes of smallholder maize farmers' in Gabaza village regarding their choice to diversify their income. The results shows that most farmers (61, 5%) did not diversify their income streams while a smaller proportion of smallholder maize farmers did diversify their income streams (38, 5%). Dependence on traditional farming, lack of knowledge about alternative practices, and risks associated with change contributed to reluctance to diversify income streams. Moreover, the decision to diversify is impacted by multiple factors, including proximity to the market, educational background, support services, and others.

4.5.3 Income diversification among smallholder maize farmers included in the sample in Giyani.

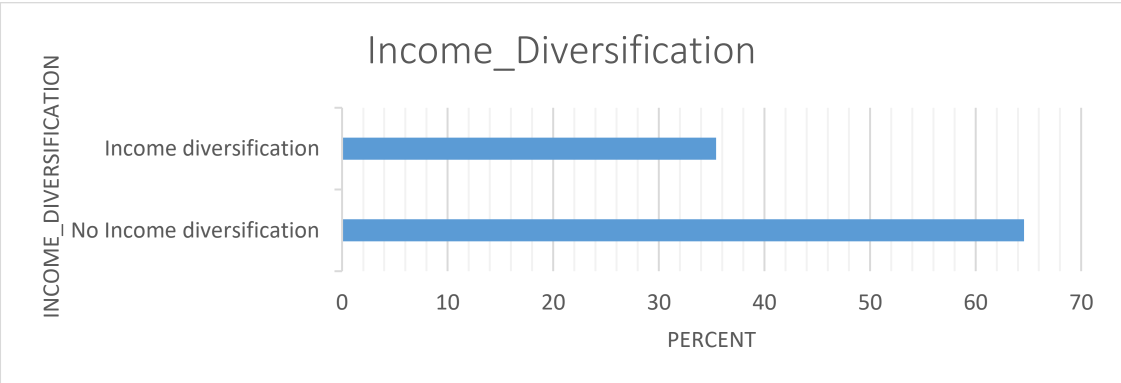

Figure 4.10 Sampled smallholder maize farmers' decision on income diversification in Giyani

Source: Author compilation from survey data, 2023.

4.6 Crop diversification of the sampled smallholder maize farmers in in the study area

Studies indicate that the variety of crops grown has a significant impact on the productivity and financial gains of smallholder farmers, emerging as a cost-effective risk management technique to reduce uncertainty at the farm level (Shahbaz et al., 2017). Through the cultivation of a diverse array of crops, smallholder farmers can alleviate the impacts of unpredictable weather, pests, and market fluctuations, leading to enhanced farm productivity and profitability. This approach helps distribute risks and provide safeguard against potential future losses.

4.6.1 Crop diversification among sampled smallholder maize farmers in Ga-Makanye

Table 4.1: Crop diversification of sampled smallholder maize farmers in Ga-Makanye

Climate-Smart Agricultural practice	Frequency	Percentage (%)
Crop diversification	13	50
No Crop diversification	13	50

Source: Author compilation from survey data, 2023.

Table 4.1 shows that 50% of the sampled smallholder maize farmers, specifically the first 50% indicated are solely focused on cultivating and harvesting maize as their primary crop. This means that they do not engage in diversifying their production by cultivating other crops such as tomatoes, potatoes etc. On the other hand, the remaining 50% of smallholder maize farmers do not limit themselves to growing maize alone. They reported that they actively diversify their crop production by cultivating various crops such as tomatoes, spinach, and carrots in the area.

4.6.2 Crop diversification of the sampled smallholder maize farmers in Gabaza

Table 4.2: Crop diversification of sampled smallholder maize farmers in Gabaza village

Climate-Smart Agricultural practice	Frequency	Percentage (%)
Crop diversification	72	82, 8
No Crop diversification	15	17, 2

Source: Author compilation from survey data, 2023.

Based on the findings presented in Table 4.2, a substantial majority of smallholder maize farmers in the region, comprising 82, 8% (72 individuals) actively engage in diversifying their crop production. This indicates that these farmers do not solely rely on maize cultivation, but rather engage in growing a variety of crops such as peanuts, butternuts, sweet potato, and groundnuts. By varying the crops, they produce, these farmers can increase the variety of income streams available to them, as well as improve household food security and consumption. Conversely, a lesser percentage of farmers, 17, 2% (15)—only specialize on growing maize and do not diversify their crop production instead, they mostly cultivate maize.

4.6.3 Crop diversification of the sampled smallholder maize farmers in Giyani

Table 4.3: Crop diversification of sampled smallholder maize farmers in Giyani (Dzingidzingi village)

Climate-Smart Agricultural practice	**Frequency**	**Percentage (%)**
Crop diversification	31	31, 2
No Crop diversification	66	68, 8

Source: Author compilation from survey data, 2023.

According to the outcome shown in Table 4.3, larger proportion of sampled maize farmers in Giyani, Dzingidzingi village (n=96) constituting 68, 8% (66) do not diversify their crop production, implying that farmers solely produce maize as their main crop. Furthermore, smaller percentage of 31, 2% (31) diversify their crops in a sense that they do not only produce maize. Farmers have indicated that, they also grow tomatoes, orchard trees such as avocadoes, lemons, and oranges.

4.7 Sampled smallholder maize farmers' access to extension services in Ga-Makanye, Gabaza, and Giyani

Table 4.4: Sampled smallholder maize farmers' access to extension services in Ga-Makanye, Gabaza, and Giyani

Accessibility to extension services	Frequency	Percentage (%)
Ga-Makanye		
Access to extension services	16	59, 3
No access to extension services	11	40, 7
Gabaza		
Access to extension services	58	66, 7
No access to extension services	29	33, 3
Giyani		
Access to extension services	49	49
No access to extension services	47	51

Source: Author compilation from survey data, 2023.

According to the results shown in Table 4.4, greater proportion of farmers have access to extension services. Around 59, 3% of smallholder maize farmers (16) in Ga-Makanye had access to extension officers while about 40, 7% (11) did not have access. The Table 4.4 shows that in Gabaza, there was a larger percentage of farmers who utilize extension services. Around 66, 7% of smallholder maize farmers (58 individuals) in the region had access to extension services, suggesting that they receive less information and assistance in their crop production. Conversely, a larger proportion, about 51%, of farmers in the area do not have access to extension services. The reasons for farmers' lack of access vary, including disparities unavailability between the extension officers and them. Some farmers cited constraints like limited time and other responsibilities, such as work commitments, which prevents them from connecting with these officers. This suggests the need for extension officers in the regions to establish diverse schedules and appointments, ensuring that all farmers can equally benefit from these extension services (derive highest level of utility). The lack of awareness about extension services is one of reasons cited by farmers for not utilizing them.

4.7.1 Sampled smallholder maize farmers' information about climate-smart agriculture (CSA) in Ga-Makanye, Gabaza, and Giyani

Table 4.5: Sampled smallholder maize farmers' information about CSA in Ga-Makanye village, Gabaza, and Giyani

Information about climate-smart agriculture	Frequency	Percentage (%)
Ga-Makanye		
Have information about CSA	13	50
Have no information CSA	13	50
Gabaza		
Have information CSA	39	44, 8
Have no information about CSA	48	55, 2
Giyani		
Have information about CSA	44	45, 8
Have no information about CSA	52	54, 2

Source: Author compilation from survey data, 2023.

Table 4.5 demonstrates the distribution about information related to CSA among smallholder farmers sampled (n=209) in Ga-Makanye, Gabaza, and Giyani. The results show an equal distribution of information among maize farmers in Ga-Makanye with 13 farmers (50%) each having knowledge about CSA and not knowing any information or heard about CSA within their farming years. The results indicate that 55, 2% (48) maize farmers have never heard/ know any information about CSA while 44, 8% (39) maize farmers have heard and know information about CSA. It is evident that larger number of farmers do not have essential information about various ways of mitigating and adapting towards climate change risks.

Lastly, the results indicate that about 54, 2% (52) number of smallholder maize farmers have no access to information about CSA or climate change mitigating strategies to use in Giyani (Dzingidzingi Village). On the other hand, smaller portion of farmers who had access to information about CSA are equivalent to 45, 8% (44). This small portion of results show that, there should be improvement towards developing farmers as there is a considerable number of farmers with information about CSA although, they are very few.

4.8 Exposure to climate risks for the sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani

4.8.1 Exposure to climate risks for the sampled smallholder maize farmers in Ga-Makanye

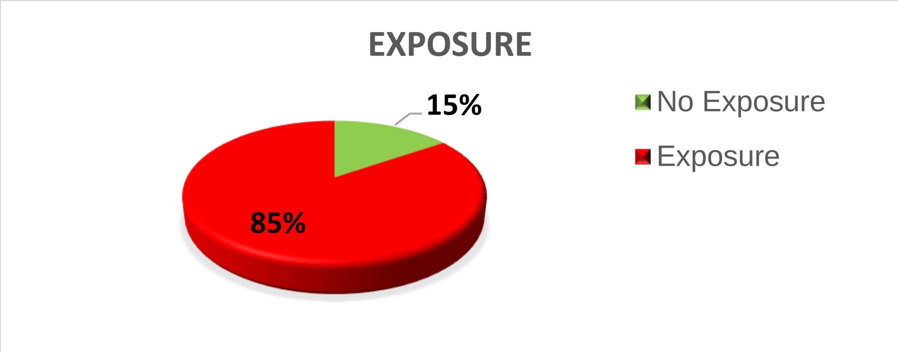

Figure 4.11: Exposure to climate risks for the sampled smallholder maize farmers in Ga-Makanye

Source: Author compilation from survey data, 2023.

The results presented in Figure 4.11 indicate that larger proportion of the sampled maize farmers 85% (23) are exposed to climate change risks while 15% (4) are not exposed to climate risks. This implies that a greater share of farmers was exposed to pests' damages, elevated temperatures and lack of rainfall in a longer period of 6 months. This is due to not having resources to irrigate their crops.

4.8.2 Exposure to climate risks for the sampled smallholder maize farmers in Gabaza

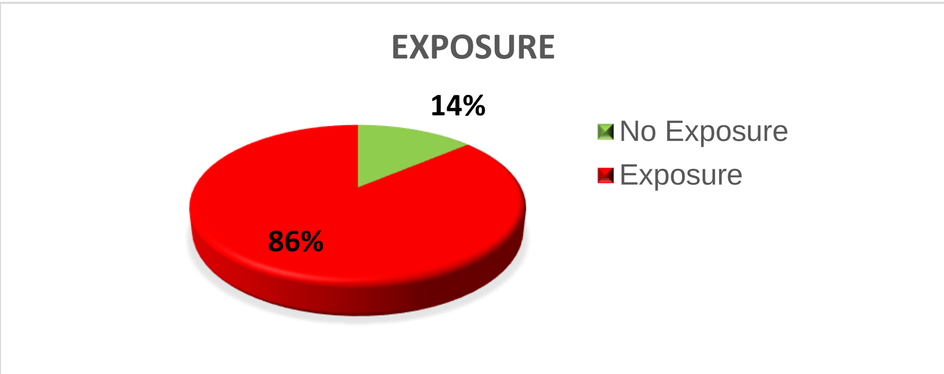

Figure 4.12: Exposure to climate risks for the sampled smallholder maize farmers in Gabaza

Source: Author compilation from survey data, 2023.

The results obtained from the sampled smallholder maize farmers in Gabaza Village presented in Figure 4.12 illustrates a higher percentage of farmers 86% (75) who were exposed to climate risks while smaller portion of farmers 14% (12) were not exposed to these risks posed by climate change. These results imply that Gabaza smallholder maize farmers were threatened by pests' damages, extreme temperatures, frosts, and lack of rainfall in a longer period. Additionally, farmers indicated that due to poor funds and availability of resources, they rely on rainfall to irrigate their crops.

4.8.3 Exposure to climate risks for the sampled smallholder maize farmers in Giyani

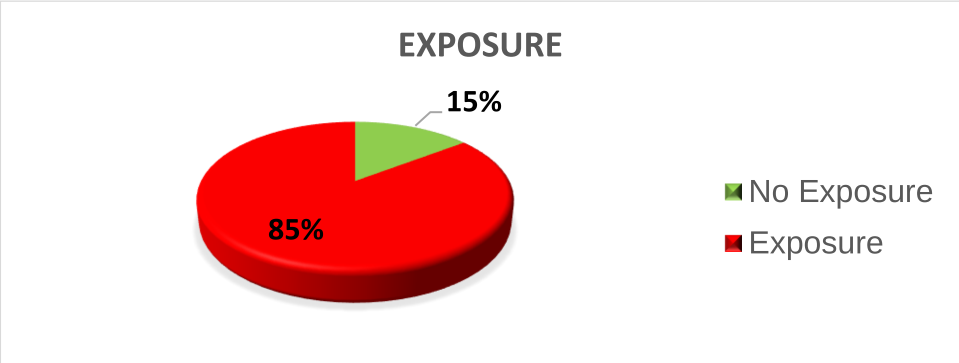

Figure 4.13 Exposure to climate risks for the sampled smallholder maize farmers in Giyani (Dzingidzingi Village)

Source: Author compilation from survey data, 2023.

Figure 4.13 present results from the total sampled smallholder maize farmers (n=96). The findings indicate that a larger proportion of farmers, 85% (82) were exposed to climate risks particularly extreme temperatures that are hot and dry. This exposure implies that farmers were vulnerable to hot weathers that are dry and results in little rainfall in the seasons. Furthermore, farmers indicated that pest damages also affect their yields and crop quality as it hinders proper grown with all the nutrients required.

On the other hand, an exceptionally low percentage of farmers of about 15% (14) were not exposed to climate risks. Farmers noted that they were not exposed to climate risks, although they experience same hot and dry temperatures. This because they mostly irrigate their crops and did not rely on rainfall for irrigation purposes. Furthermore, farmers occupy a small piece of land in hectares, and for this reason, the impact was limited as compared to those with larger hectares.

4.9 Sensitivity to climate change risks for the sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani

4.9.1 Sensitivity toto climate change risks for the sampled smallholder maize farmers in Ga-Makanye

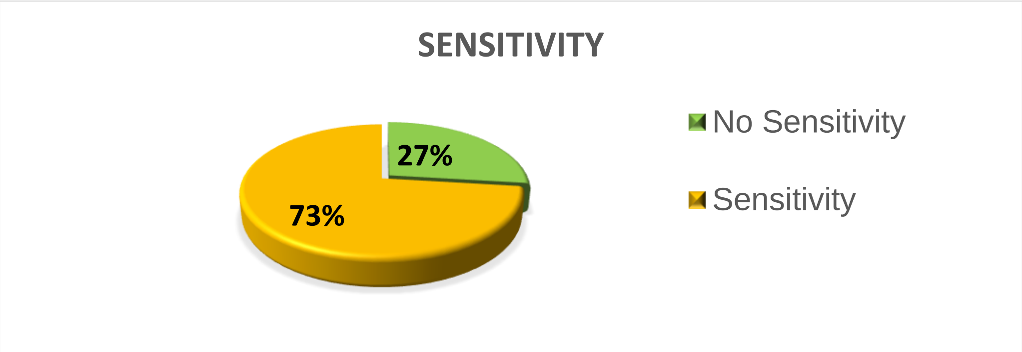

Figure 4.14: Sensitivity to climate change risks for the sampled smallholder maize farmers in Ga-Makanye

Source: Author compilation from survey data, 2023.

The results on Figure 4.14 shows that a larger percentage of smallholder maize farmers in Ga-Makanye village are sensitive to climate change risks and it further shows that farmers are vulnerable. The percentage of farmers that were sensitive to climate risks is 73% (19) while a smaller percentage of maize farmers 27% (7) were not sensitive to climate risks within Ga-Makanye. This implies that those farmers who were sensitive to climate risks, were most likely to find ways to adapt towards these risks such as mulching their plots to reduce the high evaporation rate after irrigating their plants. Moreover, farmers who were not sensitive were not subjected to elevated temperatures because they were using shades to protect their crops. Farmers in Ga-Makanye emphasized that due to pests' damages caused by caterpillar/ worm and extremely high temperatures with less rainfall, they are more sensitive to climate change.

4.9.2 Sensitivity to climate change risks for the sampled smallholder maize farmers in Gabaza

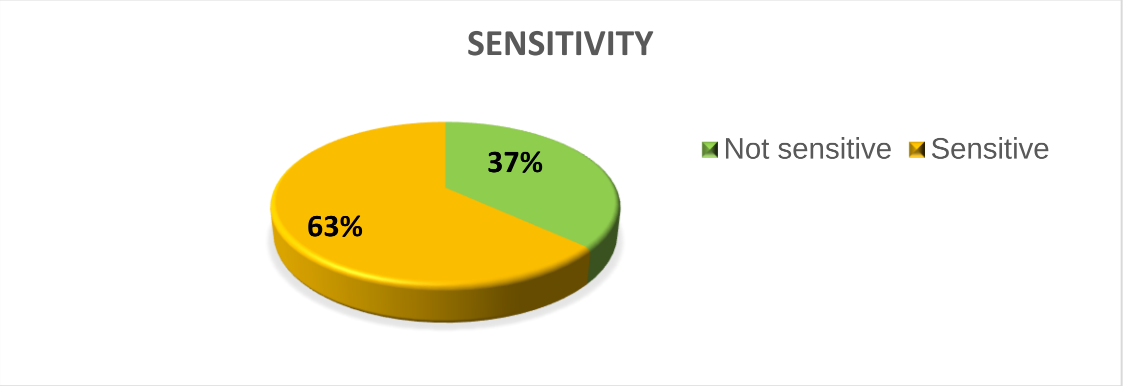

Figure 4.15 Sensitivity to climate change risks for the sampled smallholder maize farmers in Gabaza

Source: Author compilation from survey data, 2023.

The findings presented in Figure 4.15 indicate that a considerable proportion of smallholder maize farmers in Gabaza were sensitive/responsive to dangers arising from climate change. Additionally, the findings indicate that these farmers were exposed to vulnerabilities. Specifically, 63% (55) of farmers demonstrated a high sensitivity to climate-related risks, while a smaller portion of maize farmers, constituting 37% (32), displayed a lack of sensitivity to such risks Gabaza. However, this distribution of sensitivity imply that more farmers are sensitive towards climate risks. Nevertheless, this distribution of sensitivities underscores the fact that there are more farmers who are responsive to climate risks. Importantly, the prevailing trend of higher sensitivity among farmers indicate their susceptibility to the impacts of climate change. Farmers have communicated that those factors such as pests,’ damages, extreme temperatures, and poor rainfall distribution in a brief period contribute to reduced yields and profits in their small hectares of land.

4.9.3 Sensitivity to climate change risks for the sampled smallholder maize farmers in Giyani

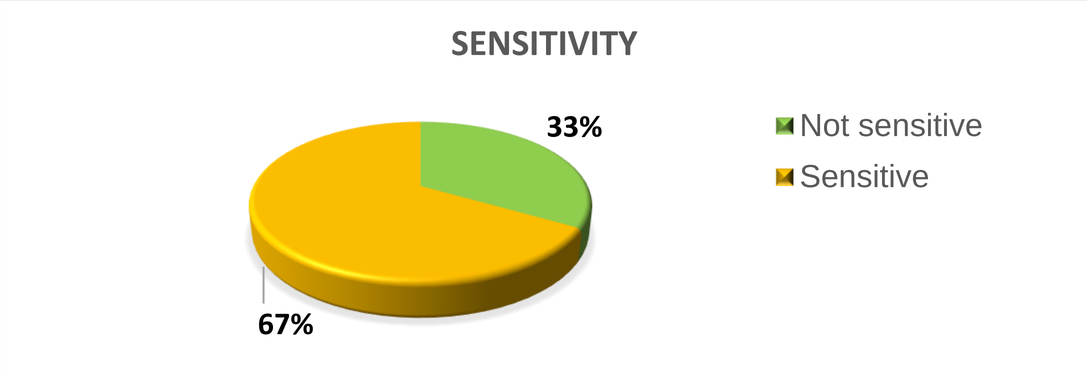

Figure 4.16: Sensitivity to climate change risks for the sampled smallholder maize farmers in Giyani (Dzingidzingi Village)

Source: Author compilation from survey data, 2023.

The outcomes in Figure 4. 17 show that, 67% (64) number of farmers in the area are sensitive towards climate risks while 33% (32) percentage of farmers are not sensitive to risks posed by climate change sampled from farmers in Giyani. This implies that, farmers that are sensitive to these risks have more chances of being exposed and vulnerable to feverish temperatures with dry winds, less rainfall and pest damages that affect the quality and market value of the crop produced. The next chapter will delve deeper into the vulnerability assessment, exploring farmers' sensitivity, exposure, and adaptive capacity

4.10 Sampled smallholder maize farmers' cooperative membership in Ga-Makanye, Gabaza, and Giyani

Table 4.6: Sampled smallholder maize farmers' information about climate-smart agriculture in Ga-Makanye Village, Gabaza, and Giyani.

Farmers' cooperative membership	**Frequency**	**Percentage (%)**
Ga-Makanye		
Farmer forms part of a cooperative	9	36, 4
Farmer does not form part of a cooperative	17	65, 4
Gabaza		
Farmer forms part of a cooperative	18	20, 7
Farmer does not form part of a cooperative	69	79, 3
Giyani		

Farmer forms part of a cooperative	15	15, 6
Farmer does not form part of a cooperative	81	84, 4

Source: Author compilation from survey data, 2023.

Table 4.6 depicts results for sampled (N=209) smallholder maize farmers' cooperative membership in the selected areas of Ga-Makanye, Gabaza, and Giyani. The results illustrate that for all the areas, there is larger proportion of farmers' non-participation in agricultural cooperatives with, 65, 4%, 79, 3%, and 84, 4% in Ga-Makanye, Gabaza, and Giyani, respectively. On the other hand, a smaller number of smallholder farmers were involved in cooperatives, 36, 4%, 20, 7%, and 15, 6% in Ga-Makanye, Gabaza, and Giyani, respectively.

4.11 Measures of dispersion of the sample smallholder maize farmers in the selected area

4.11.1 Measures of dispersion of the sample smallholder maize farmers in Ga-Makanye (n=26)

Table 4.7: Tabulated measures of dispersion of the sampled smallholder maize farmers in Ga-Makanye

Variable	Mean	St Deviation	Min	Max	T-test (Sig. 2-Tailed)
Age (years)	60	18, 57	21	83	51, 7**
Experience (years)	24	20, 59	3	70	78, 9**
Household size (per head)	5	2, 21	2	11	93, 2**
Farm size (hectares)	4	4, 63	0, 50	19	60, 7**

Source: Author compilation from survey data, 2023.

Notes: ** indicates statistical significance at a level of 5%

Based on the outcome presented in Table 4.7, the average age of the sampled smallholder maize farmers was 60 years old, and they possess 24 years of experience, ranging from a minimum of 3 to a maximum of 70 years of experience. The two-tailed t-test indicated a highly significant mean difference between the years of experience and the age of the maize farmers at the 5% significance level. Additionally, the results shown in Table 4.7 revealed a substantial mean difference between the size of the farm (measured in hectares) and the number of household members living with the farmer. On average, farmers lived with five people, with a minimum of 2 and a maximum of 11 individuals in one household. Furthermore, farmers exhibited a mean difference of 4 hectares of land, ranging from a minimum 0 of 50 hectares to 19 hectares in their fields. The two-tailed t-test for the results related to farmers' household size and farm size demonstrated statistical significance at the 5% level, indicating strong evidence of a significant difference between the number of people living with the farmer and the farm size. The implication is that a larger household size a farmer tends to have, resulted in a smaller farm, and a smaller number of people living with the farmers leads to a larger farm size.

4.11.2 Measures of dispersion of the sample smallholder maize farmers in Gabaza (n=87)

Table 4.8: Tabulated measures of dispersion of the sampled smallholder maize farmers in Gabaza

Variable	Mean	St Deviation	Min	Max	T-test (Sig. 2-Tailed)
Age (years)	67	14, 75	23	94	37, 9**
Experience (years)	25	19, 57	1	75	16, 2**
Household size (per head)	5	3, 04	1	14	28, 5**
Farm size (hectares)	2	1, 20	0, 25	8	60, 3**

Source: Author compilation from survey data, 2023.

Notes: ** indicates statistical significance at a level of 5%

Table 4.8 displays the average age and experience level (i.e., years of practicing agriculture) of the smallholder maize farmers sampled. The minimum age was 23 and 1 year, and the maximum age was 75 and 94 years, respectively. The findings of the two-tailed t-test showed that the mean difference between the maize farmers who were aged 0, 379 and those who had level experience 0, 162 years was extremely significant (at the 5% level of significance). Despite this, the t test indicates that the values were below the 95% significance threshold, suggesting that the mean values of the farmer's age and experience do not significantly differ from one another. Additionally, the results indicate that the mean average of the farmer was found to have lived with 5 people, with minimum of 1 person and maximum of 14 people in one household. Alternatively, a farmer was found to have a mean difference of 2 hectares of land with minimum of 0, 25 (quarter of a hectare) and maximum of 8 hectares in their fields. The two-tailed t test of the results for farmers' age and agricultural experience was significantly levelled at 95%. This infer that there is strong evidence that there the older the farmer, the more experienced they are and the younger the farmer, the less agricultural experience they obtained.

4.11.3 Measures of dispersion of the sample smallholder maize farmers in Giyani (n=96)

Table 4.9: Measures of dispersion of the sampled smallholder maize farmers in Giyani

Variable	Mean	St Deviation	Min	Max	T-test (Sig. 2-Tailed)
Age (years)	64	13, 75	30	85	17, 0**
Experience (years)	27	16, 04	12	60	95, 9**
Household size (per head)	6	2, 37	0	12	3, 2**
Farm size (hectares)	2	1, 99	0, 25	12	78, 7**

Source: Author compilation from survey data, 2023.

The results shown in Table 4.9 show that the sampled smallholder maize farmers' average age and degree of experience, or the number of years they had been farming, were 64 and 27, respectively, with a minimum of 30 and 12 years and a maximum of 85 and 60 years, respectively. The findings of the two-tailed t-test showed that the mean difference between the maize farmers who were aged 0, 017 and those who had level experience 0, 959 years was extremely significant (at the 5% level of significance). Even still, the t test indicates that the values are more than the 95% significance level, suggesting that the mean values of the farmer's age and experience do not significantly differ from one another. Additionally, the results indicate that the mean average the farmer was found to have lived with 6 people, with minimum of 0 and maximum of 12 people in one household. Alternatively, a farmer was found to have a mean difference of 2 hectares of land with minimum of 0, 25 (quarter of a hectare) and maximum of 12 hectares in their fields. The two-tailed t test of the results for farmers' household size, farm size, age and experience were significantly tested at 95%. This infer that there is strong evidence that there the t test values are smaller than the 95% significance level whereby the household size had 0, 32 t test while farm size had 0, 787 value.

4.12 Measures of dispersion of the categorical data, and chi-square test for the sampled variable to be used in Probit model.

The Pearson Chi-square test is employed to evaluate the variances between proportions observed and those expected. The study selected this test as an appropriate and significant test to check the statistical significance of categorical data selected as dummy variables to address the willingness to adopt CSA. The study did not aggregate the variables to avoid biased results.

4.12.1 Measures of dispersion of the sampled variables and Pearson chi-square test for variables used in Probit model for Ga-Makanye (N=26)

Table 4.10: Measures of dispersion of the sampled variables and Pearson Chi-square test for variables used in Probit model for Ga-Makanye

Explanatory variables	A Total observed. N= 26	B W=0	C W=1	Pearson chi-square (p, <0,05)
Education				
No education	4	0	4	0, 219
Primary	7	3	4	
Secondary	11	2	9	
Tertiary	4	0	4	
% of males	13	2	11	0, 619
% of females	13	3	10	
Income diversification (1= yes)	10	0	10	0, 049**
Crop diversification (1=yes)	13	1	12	0, 135
Access to extension services (1=yes)	16	3	13	0, 937
Information about climate-smart agriculture (1=yes)	13	1	12	0, 135
Exposure (1=yes)	22	5	17	0, 289

Sensitivity (1=yes)	19	4	15	0, 698
Cooperative membership (1=yes)	9	3	6	0, 184

Source: Author's compilation from survey data, 2023.

Notes: **, and * denotes the significance levels of 5% and 10%, respectively.

Table 4.10 displays the results derived the Pearson Chi-square test, conducted to examine the disparity between the dependent variable and chosen independent variables. According to the table, income diversification was identified as statistically significant at 5% level, indicating a noteworthy associated with the willingness adopt CSA practices among farmers. This means that, when farmers diversify their income in different production stages, they can easily adopt CSA practices to curb climate change risks. Income diversification is dependent on WTACSA.

4.12.2 Descriptive statistics of the sampled variables and Pearson chi-square test for variables used in Probit model for Gabaza (N=87)

Table 4.11: Descriptive statistics of the sampled variables and Pearson chi-square test for variables used in Probit model for Gabaza.

Explanatory variables	**A Total observed. N= 87**	**B W=0**	**C W=1**	**Pearson chi-square (p, <0,05)**
Education **No education** **Primary** **Secondary** **Tertiary**	 29 21 24 13	 17 5 4 3	 12 16 20 10	0, 005**
% of males **% of females**	20 67	6 23	14 44	0, 719
Income diversification (1= yes)	37	7	30	0, 014*
Crop diversification (1=yes)	72	22	50	0, 229
Access to extension services (1=yes)	58	13	45	0, 002**
Information about climate-smart agriculture (1=yes)	39	5	34	< 0, 001***

Exposure (1=yes)	75	25	50	1, 000
Sensitivity (1=yes)	55	21	34	0, 208
Cooperative membership (1=yes)	18	4	14	0, 261

Source: Author's compilation from survey data, 2023.

Notes: ***, **, and * denotes the significance levels of 1%, 5% and 10%, respectively. W=0 denotes the unwillingness to adopt CSA, and W=1 denotes the willingness to adopt CSA by smallholder maize farmers

The results presented in Table 4.11 shows that income diversification was found to be statically significant at 10%, while farmers' level of education, access to extension services were statistically significant at 5% level of significance. Lastly, information about CSA was highly statistically significant at 1%. The results imply that additional one year in farmers' education, access to extension services will improve the willingness to adopt by 1%. Furthermore, when farmers have access to information about CSA and diversify their income streams, they can easily adopt the improved agricultural practices as a resilient measure. Income diversification, education, access to extension services, and information about CSA are influencing the willingness to adopt CSA implying that these factors have a positive influence towards farmers' adoption decision.

Descriptive statistics of the sampled variables and Pearson chi-square test for variables used in Probit model for Giyani (N=96)

Table 4.12: Descriptive statistics of the sampled variables and Pearson chi-square test for variables used in Probit model for Giyani (Dzingidzingi Village)

Explanatory variables	**A Total observed. N= 96**	**B W=0**	**C W=1**	**Pearson chi-square (p, <0,05)**
Education **No education** **Primary** **Secondary** **Tertiary**	 41 34 11 10	 24 8 2 2	 17 26 9 8	0, 003**
% of males **% of females**	28 68	11 25	17 43	0, 817
Income diversification (1= yes)	34	9	25	0, 098

Crop diversification (1=yes)	30	5	25	0, 004**
Access to extension services (1=yes)	49	25	24	0, 005**
Information about climate-smart agriculture (1=yes)	44	14	30	0, 290
Exposure (1=yes)	82	27	55	0, 025**
Sensitivity (1=yes)	64	23	41	0, 655
Cooperative membership (1=yes)	15	5	10	0, 717

Notes: **, and * denotes the significance levels of 5% and 10%, respectively.

Source: Author's compilation from survey data, 2023.

W=0 denotes the unwillingness to adopt CSA, and W=1 denotes the willingness to adopt CSA by smallholder maize farmers

The results of this unique study shed light on the interplay between the explanatory variables and the dependent variable (see Table 4.12). Significantly, at the 5% level, the study reveals that exposure to climate hazards, crop diversification, education, and availability of extension services for smallholder farmers are key factors. This novel finding suggests that a 1% increase in education, access to extension services, crop diversification, and exposure to climate risks can significantly influence farmers to adopt CSA techniques, thereby enhancing their production and profitability.

In line with the current study's findings, more farmers have completed secondary education, according to studies by Mogaka *et al*. (2021) and Senyolo *et al*. (2021). Nevertheless, several studies dispute the results of this study, contending that because smallholder farmers are often older, most of them only completed primary education (Abegunde et al., 2020; Mogaka et al., 2021; Waaswa et al., 2021). Additionally, the results of the Mogaka *et al*. (2021) study are at odds with the findings of this study, which show that there are more male-headed farmers than female farmers cultivating crops. This is because women were found to have lower levels of education, making them less knowledgeable and unable to learn new information. However, additional research supports the findings of this study that more women are engaged in agricultural practice. Additionally, the outcomes of the study by Dung (2020) reported that more farmers were willing to adopt climate-smart agriculture, agreeing with the results of this study. This infers that various pieces of literature confirm the results of this current study.

4.13 Chapter overview

In this chapter, a thorough account of descriptive findings has been presented, focusing on the socioeconomic attributes of smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani. The results strongly indicate that among the sampled farmers in the selected areas, female predominate in Giyani and Gabaza, accounting for 70, 8% and 77%, respectively. Additionally, the results further demonstrated sufficient evidence that the study areas differ in terms of agro-ecological zones as farmers were found to be different as one area experienced more humidity and rainfall while other areas never received any rainfall at a particular tie period. A percentage of 85%, 86%, and 85% farmers in Ga-Makanye, Gabaza, and Giyani were highly exposed to climate risks, respectively. The notable climate change risks such as pests' damages, high temperatures, less rainfall, and dry weathers at one place while other experience frequent rainfall distribution at short period of time. Moreover, 73%, 63%, and 67% farmers at the selected places were sensitive to these risks posed by climate change. The results also showed that there are more farmers who did not receive any form of formal education in areas of Gabaza and Giyani, implying that farmers were illiterate (did not go to school)

CHAPTER 5: EMPERICAL RESULTS AND DISCUSSION

5.1 Introduction

This section presents the findings related to the second and third objectives, aimed at smallholder maize farmers vulnerability assessment towards the risks posed by climate change and the factors influencing the willingness to adopt CSA by smallholder maize in Ga-Makanye, Gabaza, and Giyani in Limpopo Province, South Africa. In this chapter, the results of Vulnerability assessment and Double-Hurdle model are presented and discussed.

5.2 Smallholder maize farmers' vulnerability assessment

Various authors mentioned that vulnerability assessments that are related to smallholder livelihoods and their agricultural production are more related to livelihood and social vulnerabilities (Williams et al., 2018; Dobkowitz et al., 2020; Derbile et al., 2022). More appropriate knowledge, comprehension, and useful advice to assist farmers in making decisions are anticipated from the assessment (Williams et al., 2018). Although, vulnerability assessment mainly focuses on susceptibility of only agricultural activities such as environmental factors, pests and diseases, and market fluctuations. According to the FaVI rating index, there are five levels of vulnerability: very low (0 – 0, 19), low (0 – 0, 39), moderate (0 – 0, 59), high (0 – 0, 79), and very high (0 – 0, 81).

5.2.1 Smallholder maize farmers' vulnerability assessment in Ga-Makanye.

Table 5.1: Smallholder maize farmers in Ga-Makanye vulnerability assessment (n= 26)

Source: Author's compilation from survey data, 2023.

$$FaVI = \frac{total\ scores\ of\ indicators}{no.of\ variables}$$

No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)	No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)
1.	5	4, 33	8	0, 91	**14.**	4, 33	4	8	0, 86
2.	2.67	4	6	0, 67	**15.**	1	4	1	0, 32
3.	1.67	2, 67	1	0, 28	**16.**	2	4	4	0, 53
4.	1.67	3, 33	7	0, 63	**17.**	1	4	3	0, 42
5.	4	3, 67	6	0, 72	**18.**	5	2, 67	4	0, 61
6.	1.67	2, 67	7	0, 60	**19.**	2, 67	1, 67	0	0, 22
7.	1.67	1, 33	7	0, 53	**20.**	2	4, 33	4	0, 54
8.	4	3, 67	5	0, 67	**21.**	2	4	2	0, 42
9.	1.67	3, 67	4	0, 49	**22.**	3	4	4	0, 58
10.	3	5, 67	8	0, 88	**23.**	4	5	5	0, 74
11.	4	6	1	0, 58	**24.**	2	3, 33	5	0, 54
12.	5	5, 67	1	0, 61	**25.**	0	1	4	0, 26
13.	4.67	4	6	0, 77	**26.**	2	2, 67	8	0, 67

FaVI rating index, 0 – 0, 19 very low vulnerability; 0, 20 – 0, 39 Low vulnerability; 0, 40 – 0, 59 Moderate vulnerability; 0, 60 – 0, 79 high vulnerabilities; and 0, 80 ≤ 1 very high vulnerability.

The results in Table 5.1 show the calculated vulnerability index for maize smallholder farmers in a rural area of Ga-Makanye in Limpopo Province. The results show that smallholder farmers' vulnerability ranged from 0, 22 to 0, 91. Additionally, 11 54% of maize farmers were very highly vulnerable to climate change risks, while 38 46% were highly vulnerable to risks posed by climate change. On the other hand, 38 46% of farmers were moderate, and very few farmers 15, 38% were low vulnerable to climate change risks. Some of the reasons accounting for the vulnerability of farmers found in the area include, among others, high temperatures, relatively little rainfall received, and pests such as fall armyworm (*Spodoptera frugiperda*) and rats. The primary method by which fall armyworm causes damage to a host plant results from the feeding activity on vegetative and reproductive parts where fall armyworm larvae cause defoliation of crops, consequently harming the plants (Makgoba et al., 2021). In addition, all armyworms feed on maize growth, impairing food production and economic returns for farmers, thereby threatening their livelihoods (Tambo et al., 2021; Anjorin et al., 2022).

Figure 5.1: Fall armyworm damaged maize crop.

Source: Rural 21, International Journal for Rural development

5.2.2 smallholder maize farmers’ vulnerability assessment in Gabaza village

Table 5.2: Smallholder maize farmers' in Gabaza vulnerability assessment (n= 87)

No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)	No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)
1	1	1, 67	2	*0, 25*	**25**	1, 33	1, 67	3	*0, 32*
2	2, 33	4	4	*0, 54*	**26**	0, 67	1	2	*0, 19*
3	1, 33	2, 67	5	*0, 37*	**27**	0, 67	1	3	*0, 35*
4	1, 33	2, 67	4	*0, 42*	**28**	0, 67	3	4	*0, 42*
5	0, 67	2	2	*0, 25*	**29**	1	2	5	*0, 44*
6	1	2, 67	3	*0, 35*	**30**	1	1, 33	4	*0, 63*
7	0, 67	3, 67	6	*0, 63*	**31**	5	4	3	*0, 75*
8	5	5, 67	4	*0, 54*	**32**	3, 33	5	6	*0, 74*
9	4, 67	4, 67	3	*0, 77*	**33**	5	6	3	*0, 88*
10	4, 33	3, 33	3	*0, 56*	**34**	4	4, 67	8	*0, 63*
11	0	1, 33	5	*0, 42*	**35**	2, 33	4, 67	5	*0, 68*
12	2, 33	5	2	*0, 49*	**36**	3	5	5	*0, 74*
13	1	1, 67	6	*0, 46*	**37**	4, 33	5, 66	4	*0, 91*
14	5	4, 33	3	*0, 65*	**38**	5	4, 33	8	*0, 84*
15	0, 33	3	2	*0, 28*	**39**	5	4	7	*0, 91*
16	4	4	4	*0, 63*	**40**	4	5, 33	8	*0, 93*
17	4	3, 33	2	*0, 49*	**41**	5	4, 67	8	*0, 79*
18	0	3, 67	2	*0, 30*	**42**	3	6	6	*0, 68*
19	3	3, 67	2	*0, 61*	**43**	2	5	6	*0, 95*
20	3, 33	4	3	*0, 54*	**44**	5	5	8	*0, 63*
21	4	4, 33	8	*0, 86*	**45**	3	1	8	*0, 74*
22	4, 33	4	0	*0, 43*	**46**	5	4	5	*0, 73*
23	4	3, 33	4	*0, 60*	**47**	5	4, 67	5	*0, 77*
24	3, 33	4, 33	5	*0, 67*	**48**	2	3, 33	5	*0, 54*

$$FaVI = \frac{total\ scores\ of\ indicators}{no.of\ variables}$$

FaVI rating index, 0 – 0, 19 very low vulnerability; 0, 20 – 0, 39 Low vulnerability; 0, 40 – 0, 59 Moderate vulnerability; 0, 60 – 0, 79 high vulnerabilities; and 0, 80 ≤ 1 very high vulnerability.

No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)	No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)
49	1, 67	4	6	*0, 61*	**73**	0, 67	4, 33	4	*0, 47*
50	1, 33	5, 33	5	*0, 61*	**74**	0	3, 67	3	*0, 35*
51	3	3	5	*0, 58*	**75**	2	4, 33	8	*0, 75*
52	1, 33	4, 67	5	*0, 58*	**76**	4, 33	5	8	*0, 91*
53	2	4	5	*0, 58*	**77**	4	6	7	*0, 74*
54	1, 67	4, 67	2	*0, 44*	**78**	3	4	7	*0, 79*
55	2	4	6	*0, 63*	**79**	5	6	4	*0, 89*
56	0, 33	4, 33	2	*0, 35*	**80**	4, 33	4, 67	8	*0, 70*
57	0, 33	2, 33	2	*0, 25*	**81**	2	3, 33	8	*0, 74*
58	1	4, 33	2	*0, 30*	**82**	2	4	6	*0, 61*
59	0, 33	3, 33	2	*0, 30*	**83**	1, 33	2, 33	8	*0, 74*
60	1	3	6	*0, 53*	**84**	5	6	3	*0, 84*
61	1, 33	3	5	*0, 49*	**85**	3, 33	4, 67	8	*0, 58*
62	0, 67	3, 33	2	*0, 32*	**86**	2	4	5	*0, 67*
63	0	3, 33	2	*0, 28*	**87**	0	5, 66	7	*0, 46*
66	0, 67	4	5	*0, 51*					
67	0, 33	3, 33	3	*0, 35*					
68	5	6	3	*0, 74*					
69	6	4	3	*0, 68*					
70	0	4, 33	4	*0, 70*					
71	5	3	4	*0, 37*					
72	5	6	5	*0, 84*					

Source: Author's compilation from survey data, 2023.

Table 5.2 presents the vulnerability assessment index done in Gabaza Village outside Tzaneen town of smallholder maize farmers (n=87). The results demonstrate an index that ranges from 0, 19 (least vulnerable) to 0, 91 (highly vulnerable). Table 5.2 shows a low proportion of least vulnerable maize farmers, with 1 15% and 19 54% farmers less vulnerable to climate change risks in the area. This indicates that farmers have adapted to various improved methods to curb climate change risks, suggesting that they are less vulnerable. Although more farmers were highly vulnerable to climate change risks, 26 44% of smallholder farmers were found to be moderately vulnerable, 40 23% were highly vulnerable, and 12, 64 % were very highly vulnerable to the risks posed by climate change within their area. Farmers have noted that they are highly affected by

extreme temperatures and pest damage, such as cutworms, stalk borer pests, rats, and baboons. These results seem plausible with the findings of Matimolane *et al.* (2022) and Atedhor (2016), stating that farmers become highly vulnerable to climate variability and change due to a lack of adaptation strategies due to erratic rainfalls and increased temperatures. Likewise, the study of Jamshidi *et al.*(2019) has shown that inadequate access to water and rainfall (Haden et al., 2012), pest and disease outbreaks, and extreme temperature (Niles & Mueller, 2016; Kabir et al., 2016) and erratic rain (Vani, 2016) makes farmers vulnerable to climate change risks.

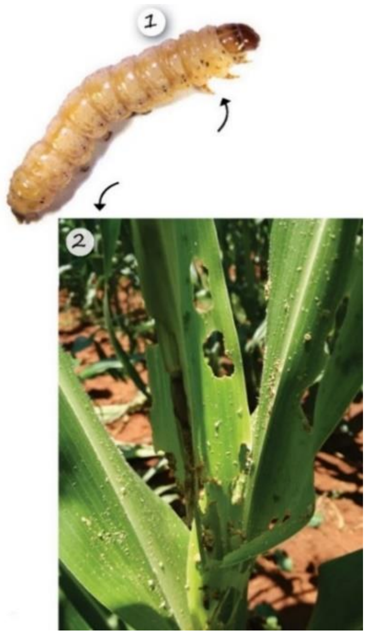

Figure 5.2: Stalk/stem borer (*Busseola fusca*) and damage cause by the species on an African maize

Source: (Strydom & Erasmus, 2020)

Figure 5.2 shows an African maize Stalk borer, which is also known as Stem borer (*Busseola fusca*) and the damage caused by the species. The pest results in crop yield bargain due to infestation that can threaten farmers' food security because it lowers the quality of food consumed (Mlanjeni, 2014).

5.2.3 Smallholder maize farmers' vulnerability assessment in Giyani

Table 5.3: Smallholder maize farmers in Giyani vulnerability assessment (n= 96)

No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)	No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)
1	1	0, 67	1	*0, 14*	**25**	5	5	1	*0, 58*
2	0, 67	1	0	*0, 09*	**26**	0, 33	2, 67	3	*0, 32*
3	1, 33	3	2	*0, 33*	**27**	2	5, 33	2	*0, 49*
4	4, 67	1, 67	0	*0, 33*	**28**	0, 67	2, 67	4	*0, 39*
5	5, 33	2, 67	3	*0, 58*	**29**	4, 67	3, 67	3	*0, 60*
6	3, 67	3, 67	8	*0, 81*	**30**	5	5, 33	2	*0, 65*
7	2, 33	3	0	*0, 28*	**31**	2, 67	2	8	*0, 67*
8	4	2, 67	2	*0, 46*	**32**	0, 67	2	1	*0, 19*
9	0	2, 67	3	*0, 30*	**33**	5	6	8	*1*
10	5, 33	4	7	*0, 86*	**34**	5	5, 67	0	*0, 56*
11	0	1, 67	1	*0, 14*	**35**	4	3, 67	6	*0, 72*
12	5, 33	5, 33	5	*0, 82*	**36**	4	4	2	*0, 53*
13	2, 33	5, 33	0	*0, 40*	**37**	4	6	8	*0, 95*
14	5	5	8	*0, 95*	**38**	5	5, 33	2	*0, 65*
15	4, 67	5	7	*0, 88*	**39**	0	5, 33	1	*0, 33*
16	3, 67	4, 67	8	*0, 86*	**40**	4	5, 33	8	*0, 91*
17	5	5, 33	8	*0, 95*	**41**	4	6	2	*0, 63*
18	0, 67	4	2	*0, 35*	**42**	0, 33	6	7	*0, 70*
19	0	2	2	*0, 21*	**43**	5, 33	5, 33	3	*0, 72*
20	5	4, 67	8	*0, 93*	**44**	3, 67	5	6	*0, 77*
21	0	1, 33	2	*0, 18*	**45**	5	0, 67	1	*0, 35*
22	0, 33	2, 33	1	*0, 19*	**46**	0, 33	6	1	*0, 39*
23	5	6	8	*1*	**47**	3, 67	5	8	*0, 88*
24	5	6	1	*0, 63*	**48**	5	6	7	*0, 95*

$$FaVI = \frac{total\ scores\ of\ indicators}{no.of\ variables}$$

FaVI rating index, 0 – 0, 19 very low vulnerability; 0, 20 – 0, 39 Low vulnerability; 0, 40 – 0, 59 Moderate vulnerability; 0, 60 – 0, 79 high vulnerabilities; and 0, 80 ≤ 1 very high vulnerability.

No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)	No.	Sensitivity	Exposure	Adaptive capacity	Farmers' Vulnerability index (FaVI)
49	5	2	4	*0, 58*	**73**	3, 67	4, 67	7	*0, 81*
50	2, 33	5, 67	3	*0, 58*	**74**	3	5	8	*0, 84*
51	3, 67	5, 33	4	*0, 68*	**75**	5	5, 33	8	*0, 96*
52	5	3	2	*0, 53*	**76**	4	5, 33	8	*0, 91*
53	3	6	0	*0, 47*	**77**	4, 67	3, 67	4	*0, 65*
54	1, 33	3, 67	1	*0, 32*	**78**	3, 67	5, 33	4	*0, 68*
55	4, 67	5	0	*0, 51*	**79**	0, 67	0, 67	1	*0, 12*
56	4	6	2	*0, 63*	**80**	3	3, 67	2	*0, 46*
57	5, 33	5, 33	8	*0, 98*	**81**	3, 33	3, 33	0	*0, 35*
58	3, 67	5, 33	4	*0, 68*	**82**	1	2	4	*0, 37*
59	5	5, 67	1	*0, 61*	**83**	3	5, 33	5	*0, 70*
60	4	5, 33	1	*0, 54*	**84**	3	3, 67	4	*0, 56*
61	4, 33	5	8	*0, 91*	**85**	1, 33	4, 67	4	*0, 53*
62	5	2, 33	2	*0, 49*	**86**	2	3, 33	8	*0, 70*
63	3, 67	6	8	*0, 93*	**87**	2, 67	5, 33	7	*0, 79*
64	3, 67	5, 67	1	*0, 54*	**88**	2, 67	5	4	*0, 61*
65	2, 67	3, 67	4	*0, 54*	**89**	3	3, 67	1	*0, 40*
66	3, 67	3, 67	4	*0, 60*	**90**	0, 67	4	4	*0, 46*
67	2, 67	4, 67	6	*0, 70*	**91**	0	3	8	*0, 58*
68	3, 67	3	4	*0, 56*	**92**	5	2, 33	6	*0, 70*
69	3	5, 33	6	*0, 75*	**93**	1	2	5	*0, 42*
70	2, 33	3	7	*0, 65*	**94**	0, 67	1, 33	2	*0, 21*
71	2, 33	3	8	*0, 70*	**95**	1	0, 67	1	*0, 14*
72	3	4, 33	8	*0, 81*	**96**	3, 67	2, 67	1	*0, 39*

Source: Author's compilation from survey data, 2023.

The vulnerability assessment results sampled from 96 smallholder maize farmer in Giyani Dzingidzingi Village are presented in Table 5.3. From the sampled farmers, it was found that 8, 33% farmers were subjected to climate change risks, 16, 67% were found to be less vulnerable to such risks. Furthermore, there are more farmers who were moderately, highly, and very highly vulnerable to risks posed by climate with 25%, 27, 08%, and 22, 92%, respectively. The results imply that farmers in the village were subjected to extreme temperatures, very little rain received, which results in dry and high temperatures experienced. Farmers in the area have indicated that there was less pests and disease damages as compared to Ga-Makanye and Gabaza Villages. The area is mainly associated with extreme temperatures, that being so, farmers mostly rely on rainfall for irrigation which limits the growth of maize produced.

Figure 5.3: Dried up field after maize harvest in Giyani and corn produced.

Source: Authors' compilation from survey data, 2023.

The basic farmers' vulnerability assessment of the three locations chosen finds that there are more farmers who are moderately and highly vulnerable to threats from climate change, indicating that these maize producers are very vulnerable. Because they are vulnerable to harsh weather, inconsistent rainfall for irrigation, pests, and diseases that can negatively impact their maize yields, productivity, and profitability—since they depend on the crop for food farmers were therefore willing to adopt CSA practices. Therefore, there is a need to analyse the factors that might affect their willingness to adopt CSA practices.

5.3 Test for multicollinearity.

It is important to examine statistical disruption before using a binary expected outcome regression model to ensure the reliability and accuracy of the model's statistical conclusions (Setshedi & Modirwa, 2020). The study excluded insurance as it had constant responses, which will lead to autocorrelation and heteroscedasticity problem. The variable of age was also omitted as it had a VIF that is equal to 2, 131 and high tolerance of 0, 466, which is closer to 0, 1 indicating slightly multicollinearity problem. Table 5.4 presents variables to be included in the Probit model, and a multicollinearity test was performed on these variables. The results indicate that there is sufficient evidence that all variables had VIF that is less than 2 and ≤ 10 (0, 4 – 0,1), with mean VIF of 1, 2885 for the sampled variables (N= 209). The results indicate that there is no multicollinearity problem in the model for sample.

Table 5.4: Diagnostics to assess the degree of multicollinearity problem among the variables included in the Probit model for sampled data (N=209)

Explanatory variables	**Collinearity statistics**	
	VIF	1/VIF
Farm size (in hectares)	1, 097	0, 911
Education level	1, 805	0, 554
Gender of the maize farmer	1, 069	0, 935
Agricultural experience	1, 900	0, 526
Household size	1, 058	0, 945
Income diversification	1, 332	0, 750
Crop diversification	1, 200	0, 833
Access to extension services	1, 169	0, 855
Information about climate-smart agriculture	1, 201	0, 833
Exposure to climate risks	1, 263	0, 792
Sensitivity to climate risks	1, 335	0, 749
Farmers' cooperative membership	1, 033	0, 968
Mean VIF	**1, 2885**	

Source: Author's compilation from survey data, 2023.

5.4 First hurdle: Probit regression model results of sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani, Limpopo Province in South Africa (n= 209).

Different studies have adopted the use Double-Hurdle model to determine the relationship between the dependent variable and explanatory variables. Numerous studies, (Diendere, 2019; Khoza et al., 2019; Hitayezu et al., 2017) have been conducted to find the willingness to adopt using binary expected outcome (Probit and Logit). This study used Double-Hurdle model to analyse the relationship between the willingness to adopt CSA and Contingent Valuation Method. The Double-Hurdle model uses two steps, firstly use Probit model and second hurdle. The Probit model was selected for this study as one of the appropriate models to address the variable to be used for first hurdle.

Table 5.5: Probit regression model results of sample smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani, Limpopo Province in South Africa (n= 209).

Parameter	**Coef.**	**Std. Err.**	**z**	**P ≤ z**
Farmers' characteristics				
Constant	0, 3029	0, 7824	0, 39	0, 700
Farm size	0, 0038	0, 0504	0, 07	0, 940
Education	0, 2961**	0, 1365	2, 17	0, 030
Gender	0, 0518	0, 2358	0, 22	0, 826
Age	-0, 0009	0, 0099	-0, 09	0, 928
Agricultural Experience	-0, 1621**	0, 0072	2, 26	0, 024
Household size	-0, 0726**	0, 0378	-1, 92	0, 055
Vulnerability indicators				
Exposure to climate risks	0, 4800	0, 3087	1, 55	0, 120
Sensitivity to climate risks	-0, 1833	0, 2387	-0, 77	0, 442
Factors influencing Willingness to adopt Climate-Smart Agriculture				
Income diversification	0, 2923	0, 2363	1, 24	0, 216
Crop diversification	0, 4276**	0, 2231	1, 92	0, 055
Access to extension services	-0, 2294	0, 2167	-1, 06	0, 290
Information about CSA	0, 5034**	0, 2199	2, 29	0, 022
Cooperative membership	-0, 1346	0, 2602	-0, 52	0, 605
Number of observations = 209				
Log Likelihood -105, 66451 Likelihood Ratio Chi2 (13) = 55, 71 Chi square (p) = <0, 001***				

Notes: **, and * denotes the significance levels of 5% and 10%, respectively.

Source: Author's compilation from survey data, 2023.

Table 5.5 shows the outcomes for the Probit model's first hurdle. A total of 209 Probit regression model observations were employed. There was statistical significance (p<0,001) in the likelihood ratio chi-square statistics that were generated. The model's goodness-of-fit is demonstrated by the findings, which indicate a well-fitting statistical model with a log likelihood of -105, 66451. Furthermore, the model's validity and relevant explanatory variables are demonstrated by a likelihood ratio chi-square of 55, 71, which is highly statistically significant at the 1% level of confidence. The specified regression model is given as follows.

$$WTAi* = 0,303 + 0,004FS + 0,296EL + 0,052GND - 0,001AG - 0,162AE - 0,073HS + 0,292ID + 0,428CD - 0,229AES + 0,503ICSA + 0,480 - 0,183S - 0,135CM + \in$$

5.5 Discussion on significant explanatory variables

5.5.1 Educational Level of smallholder maize farmers

The 5% level of significance revealed a statistically significant relationship (p < 0, 005; p = 0, 030) between the educational level (EL) of smallholder maize farmers and their willingness to adopt (WTA) CSA. This data from the findings shows that the coefficient for the variable EL is positive. The adoption rate of CSA techniques likelihood rises by 29, 61% for every year that maize farmers complete their schooling. The results' conclusion may stem from the fact that farmers with higher educational attainment—such as tertiary—are more willing to implement CSA methods since they are aware of how these practices affect their yields. This result seems to be plausible and is in line with the findings of many studies that showed educational level was positively and statistically correlate with adoption of CSA (Dung, 2020; Kalu & Mbanasor, 2023). The studies further indicated that educational achievements contribute to providing farmers with necessary skills and knowledge for implementing recommended CSA on their farms. Highly educated farmers are more likely to make informed choices and quickly adopt new farming methods.

Conversely, several writers discovered that the adoption of CSA practices was proportionally influenced by the level of education (Kurgat et al., 2018; Faleye & Afolami, 2020; Mthethwa et al., 2022; Negera et al., 2022). It follows that farmers with lower levels of education develop fewer comprehension abilities and are less conscious of climate change, which makes them less inclined to react to its impacts.

5.5.2 Agricultural experience of smallholder maize farmers

The adoption of CSA was negatively impacted by the agricultural experience (AE) of smallholder maize farmers, which was statistically significant at the 5% level of significance (p<0, 005; p= 0, 012). The data shows that the coefficient for the variable AE has a negative sign. This negative association means that for every year that smallholder maize farmers have more experience, there is a 1, 6% likelihood that they will be less willing to embrace CSA. These findings suggest that farmers with longer farming and farming practices are more likely to be aware of the risks posed by climate change and some are still reluctant by choosing indigenous knowledge than adopting these CSA practices.

These outcomes are consistent with research by Ainembabazi & Mugisha (2014), which showed that agricultural experience has a beneficial impact on CSA adoption. This is because farmers with many years of farming expertise were able to appreciate the advantages of implementing CSA principles. This outcome runs counter to research by Abegunde *et al*. (2019), which found no statistically significant relationship between farming experience and the degree of CSA practice adoption.

5.5.3 Crop diversification

Crop diversification (CD) is a statistically significant factor that favourably promotes the degree of CSA adoption among smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani, according to Table 5.5's data. The variable CD has a positive coefficient and statistical significance at the 5% level of significance (p< 0, 005; p= 0, 05). This suggests a direct correlation between farmers' desire to adopt CSA and crop diversification. Therefore, a 1% increase in farmers producing crops other than maize and diversifying their agricultural output will result in a 42, 76% increase in farmers' propensity to adopt CSA. These outcomes are consistent with research by Makate *et al*. (2016), which showed that crop variety is a key factor in climate-smart strategies to support resilience to increase the effects of climate change that affects farmers.

5.5.4 Information about climate-smart agriculture

The variable information about CSA (ICSA) was found to be statistically significant at 5% level of significance (p< 0, 005; p=0, 022). There is a positive sign attached to the coefficient of the explanatory variable. This positive sign implies a direct influence information about CSA has on the adoption of CSA practices. This indicates that 1%

increase in the information and awareness about CSA smallholder maize farmers are likely willing to adopt these practices by 50, 34%. These results imply that more information and awareness about CSA by farmers increases the likelihood of adopting CSA practices. These results agree with Makamane *et al.* (2023) that found knowledge about CSA to be positively influencing the chances of adopting CSA technologies. This imply that, when farmers are more knowledgeable and have access to information about CSA, they are more likely to adopt CSA practices.

5.5.5 Smallholder maize farmer's household size

The findings depicted in Table 5.5 shows that household size is statistically significant at 5% level of significance (p< 0, 005; p= 0, 055). The variable household size is attached to a negative coefficient, indicating a negative correlation between farmers' willingness to adopt CSA practices. This negative correlation implies that there is not much influence that farmers' household size will affect their decision of adopt CSA. Therefore, when there are more people living with the farmers it means that there is more labour reducing the likelihood of adopting CSA practices. These findings seem to be plausible with findings by Agbenyo *et al*. (2022) who also suggest that household size has no statistical influence on the level of adoption advanced technologies. The findings imply that one additional member living with the farmer will decrease the willingness to adopt the CSA practices by 7, 26%. This is because smallholder farmers rely on family labour for production, and consequently if farmers have more hands required for their produce, they are less likely to adopt the practices.

5.6 Second hurdle: Tobit regression model results of sampled smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani, Limpopo Province in South Africa (n= 209).

The results for second hurdle of the Tobit model are presented in Table 5.6. A total of 209 observations of the Tobit regression model was used. The computed likelihood ratio chi-square statistics showed statistical significance (p< 0, 001). The results show a goodness-of-fit of the model, which was well with a Log likelihood of -161, 172 indicating a perfectly fitted statistical model. Furthermore, a likelihood ratio chi-square of 57, 28 shows that the model is valid and has adequate explanatory variables.

Table 5.6: Tobit regression model results of sample smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani, Limpopo Province in South Africa (n= 209).

Parameter	Coef.	Std. Err.	t	P>|t|
Farmers' characteristics				
Constant	1, 0396	0, 6622	1, 57	0, 118
Farm size	0, 0022	0, 0428	0, 05	0, 959
Education	0, 2816**	0, 1191	2, 36	0, 019
Gender	0, 0421	0, 1956	0, 21	0, 830
Age	0, 0004	0, 0085	0, 06	0, 956
Agricultural Experience	-0, 0134**	0, 0061	-2, 21	0, 029
Household size	-0, 0061**	0, 0309	-1, 95	0, 052
Vulnerability indicators				
Exposure to climate risks	0, 4047	0, 2611	1, 55	0, 123
Sensitivity to climate risks	-0, 1463	0, 2051	-0, 76	0, 476
Factors influencing Willingness to adopt Climate-Smart Agriculture				
Income diversification	0, 2630	0, 2003	1, 31	0, 191
Crop diversification	0, 3881**	0, 1866	2, 08	0, 039
Access to extension services	-0, 1846	0, 1806	-1, 02	0, 308
Information about CSA	0, 4355**	0, 1888	2, 31	0, 022
Number of observations = 209				
Pearson Goodness-of-Fit Test	Chi- Square		Log Likelihood	Sig.
Likelihood Ratio Chi-Square (12)	**57, 28**		-161, 172	< 0, 001

Notes: **, and * denotes the significance levels of 5% and 10%, respectively.

Source: Author's compilation from survey data, 2023.

The linear regression for the second hurdle is given as follows.

$$WTAi *= 1,04 + 0,002FS + 0,282EL + 0,042GND + 0,004AG - 0,013AE - 0,006HS + 0,263ID + 0,388CD - 0,185AES + 0,436ICSA + 0,405E - 0,146S + \in$$

5.7 Discussion on significant explanatory variables

5.7.1 Educational Level of smallholder maize farmers

In the second hurdle of the model, the variable educational level was determined to be statistically significant at 5% significance level (p< 0, 005; p=0, 019). The variable had a positive sign attached to the coefficient variable showing a positive influence education has on smallholder maize farmers' level of willingness to adopt CSA (number of CSA practices willing to adopt). This positive relationship implies that, one year increase in farmers' formal education will increase the number of CSA practices they will be willing to adopt adoption rate by 28, 16%..

These results seem plausible with first hurdle results showing a positive influence of smallholder maize farmers' educational level of their willingness to adopt CSA and equation 10 in Chapter 3. If Yi > 0, it suggests that farmers with higher educational levels are more likely to adopt the CSA practices This writes down that education plays a vital role in shaping farmers decision making in terms of their willingness to adopt improved agricultural practices as farmers can easily comprehend necessary information, knowledge and skills needed, raising awareness and understanding of the adoption of improved climate change mitigation and adaptation strategies.

5.7.2 Agricultural experience of smallholder maize farmers

The empirical results dissipated in Table 5.6 shows that smallholder maize farmers' faming experience was found to be statistically significant at 5% level of significance (p< 0, 01; p=0, 029). Moreover, there is an inverse relationship between farmers' years in farming and their willingness to adopt CSA. There is a negative sign attached to the coefficient variable and it indicates an inverse influence. This means that farmers' experience does not influence the adoption level of CSA practices. The implication is that farmers' adoption decision is not highly influenced by their number in agricultural field although how badly they are affected by climate risks. The outcomes oppose the initial hurdle findings, which identified positive impact of the variable. Notably, these results align with Malila *et al.* (2023) research, indicating that increased experience in a particular farming type lowers the probability of CSA adoption. The results suggest that a 1% rise in farmers' experience won't affect the likelihood of CSA adoption by 1, 34%.

5.7.3 Smallholder maize farmers' household size

The findings proven in Table 5.6 shows that household size is statistically significant at 5% level of significance (p< 0, 005; p= 0, 052). The variable household size had a negative correlation between farmers' willingness to adopt CSA practices. This negative correlation implies that there is not much influence that farmers' household size will affect their decision of adopt CSA, meaning when there are more people living with the farmers it means that there is more labour reducing the likelihood of adopting CSA practices. These findings align with conclusions of Abgunde *et al.* (2019), showing that household size does not exert a statistically significant impact on the adoption level of CSA practices. The findings imply that one added member living with the farmer will decrease the willingness to adopt the CSA practices by 0,61%. This is because smallholder farmers rely on family labour for production, so, if farmers have more hands requires for their produce, they are less likely to adopt the practices.

5.7.4 Information about climate-smart agriculture

There is positive correlation among smallholder maize farmers' accessibility towards information about climate-smart agriculture (CSA). The information on CSA variable showed statistical significance at a 5% level (p< 0, 005; p= 0, 022). This suggests that a 1% rise in access to CSA information increases the likelihood of smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani adopting CSA practices by 43, 55%. Anuga *et al*. (2019) showed that when farmers have knowledge and information about sustainable agriculture activities such as CSA are essential towards adopting various mitigation and adaptation methods to reduce the effects of climate change. The study of Kassa *et al*. (2022) was in line with the study results, showing that 96, 5% of sampled 213 farmers were well-informed about the CSA practices implying that farmers had information about CSA. This implication mean that this influences the adoption of CSA practices among farmers.

5.7.5 Crop Diversification

Table 5.5 shows the results for the second hurdle. Crop diversification (CD) is found to be statistically significant and positively influenced the level of adoption of CSA among smallholder maize farmers in Ga-Makanye, Gabaza, and Giyani. The variable CD is significant at 5% level of significance (p< 0, 005; p= 0, 039) with a positive coefficient, implying that there is a direct relationship between crop diversification and willingness to adopt CSA among farmers. One percent increase in farmers diversifying their agricultural produce will decrease the willingness to adopt CSA by 38, 8%. These results concur with findings of Awiti (2022) saying that crop diversification positively influenced the labour cost share, implying that more labour is required in a diversifying farming system, hence, crop diversification's effects on production cost. The results do not necessarily imply to CSA but shows that crop diversification can be used as an improved farming technique to mitigate against the risks of climate change.

5.8 Chapter overview

This section presented the empirical outcomes and discourse on evaluating the vulnerability assessment of smallholder maize farmers to climate change risks. The discussion was centred on farmers' vulnerability level, their exposure and sensitivity to pest and diseases, unpredictable rainfall, and extreme temperature. Additionally, a thorough examination of the significant variables was conducted using Double-Hurdle regression model.

CHAPTER 6: SUMMARY, CONCLUSION, AND POLICY RECOMMENDATIONS

6.1 Introduction

This chapter will provide a brief overview of the research journey encapsulating the key findings of the study and literature used. In this section, a concise overview of the research objectives, rationale, methodologies employed, and the significant outcomes achieved. This will provide a comprehensive summary of the main research objectives achieved.

6.2. Summary of the study

Agricultural sector is essential to Limpopo Province's rural communities because it helped in reducing poverty and create jobs. The industry is extremely susceptible to the dangers that climate change brings. While it is a key feed crop for livestock and domestic usage, maize is vulnerable to climate change. The purpose of the study was to figure out how vulnerable South African maize farmers were to the effects of climate change and how willing they were to implement climate-smart agriculture, or CSA, in the province of Limpopo. The following objectives were set forth in the study: to profile the socioeconomic features of smallholder maize farmers in Limpopo Province, South Africa; to evaluate farmers' vulnerabilityto the risks associated with climate change; and to examine the socioeconomic determinants that impact smallholder maize farmers' willingness to adopt CSA. The study was carried out in three separate areas: Ga-Makanye, Giyani, and Gabaza, due to their agro-ecological climate zones. The study gathered information from 219 smallholder maize farmers who were specifically chosen using primary cross-sectional data. Farmers were interviewed in-person for the study using focus groups and standardized questionnaires. Three objectives were addressed using measures of dispersion, vulnerability assessment index, and the Double-Hurdle model in the analysis of the data acquired using SPSS. According to the descriptive data, in Ga-Makanye, Gabaza, and Giyani, respectively, 81%, 67%, and 63% of respondents were inclined to implement CSA. With 77% and 70,8% of the sampled farmers in Gabaza and Giyani, respectively, there were more female farmers than male farmers in Ga-Makanye. Most farmers had only a secondary education. In the chosen locations, 85%, 86%, and 85% of farmers were at risk from climate change. Farmers in Ga-Makanye concluded that 88.4% of their area was vulnerable to pest damage from fall armyworms and severe temperatures. Stalk borer damage posed a threat to 79, 31% of farmers in Gabaza, while severe temperatures, dry air, insect damage, and a lack of water posed a threat to 75% of farmers in Giyani. The econometric results indicated 5% statistically significance of the results analysed. Educational level, crop diversification, information about climate-smart agriculture (CSA) were factors that positively influenced the willingness to adopt CSA. Agricultural experience and household size negatively influenced the willingness to adopt CSA and level of adoption (number of CSA practices farmers are willing to adopt). The remaining section in this chapter will be outlined as conclusion based on the empirical results and recommendations.

6.3 Conclusion

6.3.1 Smallholder maize farmers' vulnerability to climate change risks

The study assessed smallholder maize farmers' vulnerability using vulnerability assessment index, the results obtained for the three selected areas namely, Ga-Makanye, Gabaza, and Giyani shows homogeneity in terms of farmers vulnerability towards climate change. The results from Ga-Makanye highlighted that 38, 40% farmers were moderate vulnerable, while 11, 54% and 38, 46% smallholder maize were highly and very highly vulnerable to climate change risks, respectively. This infers that, 88, 4% farmers were vulnerable to risks posed by climate change such as extreme temperatures, pest damage from fall armyworm (*Spodoptera frugigerda).* Additionally, results from Gabaza also indicate that farmers were vulnerable, with 26, 44%, 12, 64%, and 40, 23% farmers were moderate, vulnerable, and highly vulnerable to climate change risks, respectively. This also concludes that 79, 31% smallholder farmers were also vulnerable to risks posed by climate change such as extreme temperatures, pest damages from stalk borer/stem borer species (*Busseola fusca),* which affected their production output and quality of maize produced. Lastly, the results from Giyani have shown that 25% of farmers were moderate vulnerable to climate change, 27, 08% were vulnerable while 22, 92% were highly vulnerable. The results infer that a total of 75% were vulnerable to climate change risks such as dry temperatures with very little rainfall. Furthermore, farmers were also willing to adopt CSA as they were highly vulnerable to climate change risks. The results of the vulnerability assessment index provided sufficient evidence to reject the null hypothesis which stated that (*Smallholder maize farmers in selected areas of Polokwane, Tzaneen and Giyani municipalities of Limpopo Province of South Africa* *are not vulnerable to climate change risks).* Therefore, this hypothesis was rejected because smallholder maize farmers were vulnerable to climate change risks such as pest damage (fall armyworm and stalk borer worm, also extreme temperatures).

6.3.2 Socioeconomic factors influencing smallholder maize farmers' willingness to adopt CSA.

The third objective was to analyze socioeconomic factors influencing the willingness to adopt CSA. This objective was addressed using the Double-Hurdle model. The empirical findings indicated that in the first hurdle, smallholder maize farmers' willingness to adopt CSA were positively influenced by educational level (EL), crop diversification (CD), and information about CSA, while agricultural experience (AE) and negatively influenced the willingness to adopt CSA. Moreover, the results in the second hurdle indicated that smallholder maize farmers' educational level (EL) and information about CSA positively influenced the willingness to adopt CSA while farmers' agricultural experience (AE) and household size (HS) negatively influenced the willingness the adopt CSA among smallholder maize farmers in the selected areas of Limpopo Province. The results provided sufficient evidence for the null hypothesis, which stated that (*Smallholder maize farmers' socioeconomic characteristics do not significantly influence their willingness to adopt CSA in selected areas of Polokwane, Tzaneen and Giyani municipalities of Limpopo Province, South Africa*) was rejected because there are socioeconomic factors which influence significantly the willingness to adopt CSA.

6.4 Policy recommendations

The study policy recommendations will be in accordance with the study findings.

i. The study found that smallholder maize farmers in the areas of Ga-Makanye, Gabaza, and Giyani were willing to adopt climate-smart agriculture (CSA) and were highly vulnerable to risks posed by climate change as a global issue. Therefore, the study recommends that the Department of Agriculture, Land Reform and Rural Development together with various agricultural stakeholders should enhance knowledge from extension officers within the area through provision of CSA workshops, educational programs that will allow farmers to be more knowledgeable about Climate Change and CSA because it is empirical towards their decision-making process and receive certificate of competence. The workshops should allow agricultural stakeholders to interact with farmers so that farmers can have a relationship with those stakeholders for future needs and assistance.

ii. Smallholder maize farmers in the study area are vulnerable hot temperatures, pest damages which affects their harvest. As such, farmers are vulnerable to these harsh temperatures because they indicated that they do not use drought-tolerant seeds which are considered one of possible ways in which vulnerability can be reduced. The Department of Agriculture, Land Reform and Rural Development (DALRRD) should provide vulnerable farmers' who are willing to adopt CSA with drought-tolerant seeds to cope with the effects of climate change. Additionally, from the results and observation done during survey, farmers are vulnerable to pest and disease outbreak which reduces their production output and productivity. Farmers should practice crop rotation and crop diversification to minimise the loss, use Integrated Pest Management (IPM).

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APPENDICES

Appendix 1: Questionnaire

FACULTY OF SCIENCE AND AGRICULTURE

DEPARTNMENT OF AGRICULTURAL AND ANIMAL PROUCTION

SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

VULNERABILITY ASSESSMENT OF SMALLHOLDER MAIZE FARMERS TO CLIMATE CHANGE RISKS AND WILLINGNESS TO ADOPT CLIMATE SMART AGRICULTURE IN LIMPOPO PROVINCE, SOUTH AFRICA.

BY

MACHETE KOKETSO CATHRINE

(201801420)

SURVEY QUESTIONNAIRE

SUPERVISOR: PROF MP SENYOLO

CO SUPERVISOR: DR LS GIDI

UNIVERSITY OF LIMPOPO, SOUTH AFRICA

Dear Participant.

My name is Koketso Cathrine Machete, Master of Science student in agriculture (Agricultural Economics) in the Department Agricultural Economics and Animal production, School of Agricultural and environmental sciences, Faculty of science and

Agriculture, University of Limpopo, South Africa. I am conducting research on "**VULNERABILITY ASSESSMENT OF SMALLHOLDER MAIZE FARMERS TO CLIMATE CHANGE RISKS AND WILLINGNESS TO ADOPT CLIMATE SMART AGRICULTURE IN LIMPOPO PROVINCE, SOUTH AFRICA**". This questionnaire shall be used an instrument for data collection in my research study.

Please take note that the information provided in this questionnaire survey will be treated with confidentiality. The information gathered by this tool shall be used solely for the purpose of this research. No personal information of respondents and details will be used in this questionnaire and no mention of names shall be indicated in the study. Participation in this study is voluntary.

Should you have any questions or concerns about your participation in the study please contact:

Ms KC Machete on this email koketsocathy05@gmail.com or Prof MP Senyolo, Department of Agricultural Economics and Animal Production, University of Limpopo, Tel: 015 268 4628; Email: Mmapatla.senyolo@ul.ac.za

Directions: please indicate your level of agreement or disagreement with each of the following statements, make further comments where necessary. Place an "X" or tick mark in the box of your answer.

Use a or ✖ ✔

SECTION A: SOCIOECONOMIC CHARACTERISTICS OF MAIZE SMALLHOLDER FARMERS

1. Gender of maize smallholder farmer

0		**1**	
Male		Female	

2. What is the age of maize smallholder farmer?

3. Level of education

0	**1**	**2**	**3**

No education		Primary		Secondary		Tertiary	

4. Smallholder maize farmer household size

5. Marital status

0		**1**		**2**		**3**	
Single		Married		Widowed		Divorced	

6. Level of income in South African Rand monthly

7. Which of the income sources is the major source for maize smallholder farmer?

0= Pension	1= Farming	2= Part-time job	3= full-time job	4 = Social Grants	5 = Remittance

8. Means of land ownership

0= Allocated (Communal)	1= Inherited	2= Borrowed	3= Rental / Lease	4 = Bought

9. What is number of years in farming?

10. How long have been farming?

0= Less than 5 years	1= More than 5 years

11. What is the total hectare of your land?

12. What is the size of the cultivated land?

0= Quarter of the land	1 = Half of the land	2 = Total area

SECTION B: FARMERS' VULNERABILITY ASSESSMENT OF SMALLHOLDER MAIZE FARMERS TO CLIMATE RISK IN SELECTED MUNICIPALITIES OF LIMPOPO PROVINCE

Indicator variables for sensitivity	**indicator**	**Index** **(1-4)**	**Vulnerability** **(0 – 3.9)**
	Human facilities		
	House damaged		
	Productive land damaged		
	Natural resource income		
	Roads damaged		
Sub-total scores			
Indicator variables for exposure	Droughts		
	Extreme temperatures		

	Floods		
	Strong winds		
	Crop (maize) diseases		
	Availability of water		
Sub-total scores			
Adaptive capacity **(0= No; 1= Yes)**	Crop rotation		
	Crop diversification		
	Income diversification		
	Crop insurance		
	Rainwater harvesting		
	Conservation agriculture		
	site-specific nutrient management		
	agroforestry		
Total score **SoVI= (total score ÷ no. of variables)**			

Index for sensitivity– 0 = Not sensitive; 1 = sensitive; 2 = Highly sensitive; 3 = Very Highly sensitive

Index for exposure 0 = Not exposed; 1 = exposure; and 2 = high exposure; and 3 = Very high exposure

SoVI rating (0 – 0.19) very low vulnerability; (0.20 – 0.39) low vulnerability; (0.40 – 0.59) moderate vulnerability; (0.60 – 0.79) High vulnerability; and (0.80 ≤ 1) Very high vulnerability

SECTION C: THE WILLINGNESS OF SMALLHOLDER MAIZE FARMERS TO ADOPT TO CLIMATE SMART AGRICULTURE

13. Have you ever heard about climate change?

0= No	1 = Yes

14. What is your most reliable source of information on climate change?

0= Radio	1= Extension officers	2= Internet	3= Farmer to farmer	4= TV	5= Work shops

15. What major changes in weather have the maize farmers observed in the area for the past 5 years?

0= Floods	1= Prolonged droughts	2= very hot temperatures	3= very wet seasons	4= Crop diseases	5= Haven't observed any changes

16. Have you experienced early start of the rain or late start of the rain in the past 5 years?

0= No	1 = Yes

17. Has the maize farmer heard about different ways of adapting to climate change?

0= No	1 = Yes

18. What is your most reliable source of information on climate change adaptations?

0= Radio	1= Extension officers	2= Internet	3= Farmer to farmer	4= TV	5= Work shops

19. Does the farmer have access to extension officers?

0= No	1 = Yes

20. How often do you access extension officers?

0= Not often	1= Very often

21. Extension officers are knowledgeable about climate change adaptation and mitigation.

0= Strongly agree	1= agree	2= Neutral	3= disagree	4= Strongly disagree

22. Information received from extension officers about climate change support makes a difference in your crop production

0= Strongly agree	1= agree	2= Neutral	3= disagree	4= Strongly disagree

23. Have you experienced low maize crop yield over the past 1 to 3 years?

0= No	1 = Yes

24. At what stages do you practically lose your crop?

0= Germination stage	1= Vegetation stage	2= Reproduction stage	3= Maturing stage

25. What do you think are the major causes of the low yields?

0= Pest damage	1= Natural causes	2= Disease outbreak	3= Lack of farm inputs	4= Lack of water

26. Do you think the major causes of low yields affect production?

0= No	1 = Yes

27. If yes, please specify how much did the major causes of low yields have affected you

____

28. Did you experience more rainfall in the past 6 months?

0= No	1 = Yes

29. Did the rainfall damage or destroy any facilities?

0= No	1 = Yes

30. If yes, please specify.

31. There are climate smart agricultural practices which are used to address changes in climatic conditions which can be helpful towards maize crops. Which of the following are you familiar with (knowledgeable/heard of them)? Are you willing to adopt such practices if given an opportunity?

0= No	1= Yes

0= agroforestry	1= Crop insurance	2= Drought tolerant maize seeds	3= Crop rotation	4= rainwater harvesting

5= site-specific nutrient management	6= Crop diversification	7= conservation agriculture	8= other

32. Which of the following have you adopted in the last production season?

0= agroforestry	1= Crop insurance	2= Drought tolerant maize seeds	3= Crop rotation	4= rainwater harvesting
5= site-specific nutrient management	6= Crop diversification	7= conservation agriculture	8= other	

33. Are you willing to adopt any 3 the following (select at least 3 that you are most likely to adopt

0= No	1 = Yes

0= agroforestry	1= Crop insurance	2= Drought tolerant maize seeds	3= Crop rotation	4= rainwater harvesting
5= site-specific nutrient management	6= Crop diversification	7= conservation agriculture	8= other	

If no in Q33 explain the reasons

____

If, yes in Q33 explain reasons which of those (select the first 3 that you are most likely to adopt

34. Which climate smart agriculture practices have you heard about?

0= agroforestry	1= Crop insurance	2= Drought tolerant maize seeds	3= Crop rotation	4= rainwater harvesting
5= site-specific nutrient management	6= Crop diversification	7= conservation agriculture	8= other	

35. What is your most reliable source of information on these practices?

0= Radio	1= Extension officers	2= Internet	3= Farmer to farmer	4= TV	5= Work shops

36. Do you plant more than one type of crop in the any given season?

0= No	1 = Yes

37. Does the maize smallholder farmer have access to insurance?

0= No	1 = Yes

38. What kind, please specify

____
____
____
____

39. Is the maize smallholder farmer part of any cooperation in the area?

0= No	1 = Yes

40. Does the cooperative membership provide information about climate risk and CSA?

0= No	1 = Yes

41. Which climate smart agriculture practices will the farmer use to deal with climate change (changes in climatic conditions).

0= agroforestry	1= Crop insurance	2= Drought tolerant maize seeds	3= Crop rotation	4= rainwater harvesting

5= site-specific nutrient management	6= Crop diversification	7= conservation agriculture	8= other

The End of the questionnaire. Thank you for sharing your feedback, I really appreciate your time, cooperation, and honesty in answering the questions.

Appendix 2: Consent Form

CONSENT FORM TO PARTICIPATE IN RESEARCH

RESEARCH TOPIC: "VULNERABILITY ASSESSMENT OF SMALLHOLDER MAIZE FARMERS TO CLIMATE CHANGE RISKS AND WILLINGNESS TO ADOPT CLIMATE SMART AGRICULTURE IN LIMPOPO PROVINCE, SOUTH AFRICA".

Dear Participant.

You are requested to participate in in the above-mentioned research study by Ms Koketso Cathrine Machete (Department of Agricultural Economics and Animal Production, University of Limpopo). You were selected to take part and participate in this study as you are a smallholder maize farmer within Polokwane Local Municipality, Greater Tzaneen Local Municipality and Greater Giyani Local Municipality in Limpopo Province.

1. Aim of the study

The study aims to examine vulnerability of maize farmers towards climate change risks and analyse the willingness to adopt climate smart agriculture (CSA) in Limpopo Province of South Africa.

2. Participation

Kindly take note that participation will be voluntarily. Each participant will be asked to give their consent to go ahead with the study and respondents can withdraw from the study at any time without any penalty. You can also refuse to answer questions you don't want to answer and still remain in the study. The investigator/researcher may withdraw you from the study if there are circumstances which call for doing so.

3. Confidentiality

The information provided in this study will be treated with confidentiality and will be disclosed only with your permission. The information gathered by the researcher shall be used solely for the purpose of this research only. No personal information of respondents and details will be used in this study and no mention of names shall be indicated in the study.

4. Potential benefits to subjects/ society

The research will help in identifying the vulnerability assessment of smallholder maize farmers and provide workable solutions to farmers who are highly sensitive to climate change thus adopt CSA practices that will enhance their adaptive capacity and profitability.

Should you have any questions or concerns about your participation in the study please contact:

Ms KC Machete on this email koketsocathy05@gmail.com or Prof MP Senyolo, Department of Agricultural Economics and Animal Production, University of Limpopo, Tel: 015 268 4628; Email: Mmapatla.senyolo@ul.ac.za

Do you voluntarily agree to participate in this interview? **Yes, or no? If yes, please fill in your details below.**

Name of participant: ………………………………………………………

Date : ………………………………………………………

Municipality : ………………………………………………………

Farm/ Village name: ………………………………………………………

Contact details: ………………………………………………………

Appendix 3: Permission letter to tribal authorities selected areas.

PERMISSION LETTER TO CONDUCT A RESEARCH

Dear Chief/Nduna

My name is Koketso Cathrine Machete, I am a master's student from the University of Limpopo in the Department of Agricultural Economics and Animal production. I am conducting research on "*vulnerability assessment of smallholder maize farmers to climate change risks and willingness to adopt climate smart agriculture in Limpopo province, South Africa"*. I therefore request a permission to collect data in ……………………………………….. village of the ………………………………………… Greater Local Municipality.

Permission granted	
Permission not granted	

Researcher/ enumerator Signature ……………………………………

Date ………………………………………………

Thank you very much.

Appendix 4: TREC Approval Letter

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 4713, Fax: (015) 268 2306, Email: moore.hutamo@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **04 April 2023**

PROJECT NUMBER: **TREC/104/2023: PG**

PROJECT:

Title:	Vulnerability assessment of smallholder maize farmers to climate change risks and willingness to adopt climate smart agriculture in Limpopo Province, South Africa.
Researcher:	KC Machete
Supervisor:	Prof MP Senyolo
Co-Supervisor/s:	Dr LS Gidi
School:	Agriculture and Environmental Sciences
Degree:	Master of Science in Agriculture (Agricultural Economics)

PROF D MAPOSA
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) **This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**

ii) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**

iii) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

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