Investigating smallholder farmers' knowledge and perceptions on climate-resilient legumes in selected villages of Limpopo Province, South Africa: A case of tepary bean.

by

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DECLARATION

I, Palesa Cecilia Mokheseng, hereby declare that the research project entitled "INVESTIGATING SMALLHOLDER FARMERS' KNOWLEDGE AND PERCEPTIONS ON CLIMATE-RESILIENT LEGUMES IN SELECTED VILLAGES OF LIMPOPO PROVINCE, SOUTH AFRICA: A CASE OF TEPARY BEAN" is my original work. The information in this report is original. This work has not been presented to other institutions before. Where assistance was sought, it is acknowledged.

Signature:  Date: 22/02/25

DEDICATION

This study is dedicated to my late mother and my immediate relatives.

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ABSTRACT

Climate change is said to be a major hazard to global food security. Smallholder farmers from disadvantaged villages are more vulnerable to the effects of climates of change and this affects their agricultural productivity. Changes in the climate can lead to reduced crop yields, water scarcity, increased pests and diseases, and food security among other effects. It has been proposed that smallholder farmers need to react to these effects of climate change by changing the types of crops they grow, to more climate-resilient and versatile ones. Among those crops are tepary beans, which have been proven to withstand different climatic changes. Tepary beans are climate-resilient legumes native to the southwestern United States and Mexico. Not only are tepary beans climate-resilient but are also high in nutrition, rich in fibre, good source of minerals and resistant to pests and diseases.

Despite the potential benefits of tepary beans, there is not enough understanding of smallholder farmers' knowledge and perceptions regarding these climate-resilient legumes. Given these reasons it becomes relevant to investigate smallholder farmers' knowledge and perceptions on climate-resilient tepary beans. In addition to the existing body of knowledge, this study will give policymakers, academics, and development practitioners important insights and raise awareness for additional research on the role of tepary beans in promoting food security and adapting to climate change. Hence, the study aimed to investigate factors that influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in selected villages of Limpopo Province, South Africa.

This study had four objectives, namely: to profile the socio-economic characteristics of smallholder farmers, assess smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean, describe the typologies of different legume crops that smallholder farmers are knowledgeable about and those that they are planting, including challenges associated with planting these crops and finally, to analyse the socio-economic factors influencing smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean. This study was conducted in 9 selected villages of Limpopo province namely, Thabakgone, Mamotintane, Ga-Motholo, Bloodriver, Ga-Thoka, Tjiane, Mphakane, Ga-Phasha and Ga-Kobe, where a total of 100 smallholder legumes farmers were sampled using purposeful sampling. The study used both qualitative and quantitative data collected through interviews with smallholder farmers using well-structured questionnaires. The data was analysed using Statistical Package for Social Science (SPSS).

Descriptive statistics were used to to profile the socio-economic characteristics of smallholder farmers and to describe the typologies of different legume crops that smallholder farmers are knowledgeable about and those that they are planting, including challenges associated with planting these crops. In order to assess smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean, the study used Descriptive statistics by employing the Likert scale. Multinomial Logistics Regression model was used to generate the results of the socio-economic factors influencing smallholder farmers' knowledge. Binary Logistics Regression model was used to generate the results of the socio-economic factors influencing smallholder farmers' perceptions on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province.

The results of Multinomial Logistics Regression model showed that employment status, production cost, nutritional value, land size, and production cost were significant. These variables had an influence on the knowledge smallholder farmers have on climate-resilient legumes. A positive relationship between employment and knowledge of climate-resilient legumes implied that being employed is linked to an increase in the knowledge of climate-resilient legumes amongst smallholder farmers classified as having medium knowledge. The positive relationship between nutritional value and knowledge of smallholder farmers means that with knowledge of nutritional value of tepary beans are likely to adopt. The negative relationship between production cost and knowledge of climate-resilient legumes mean that high costs of production can reduce the smallholder farmers' willingness to gain knowledge.

Binary Logistic Regression model results showed that production cost, land size, marital status, nutritional value, employment and access to extension services do determine how smallholder farmers perceive climate-resilient legumes. This proposes that smallholder farmers are willing to accept higher costs if they perceive the long-term benefits of the crop in terms of climate resilience. The positive relationship between land size and smallholder farmers' perceptions towards climate resilient beans could mean that larger sizes of land influence farmers to easily adopt to new and different crops. Marital status and perceptions of smallholder farmers on climate-resilient beans have a positive relationship, which suggests that married smallholder farmers have people who depend on them and may be more open to adopting climate-resilient crops to maintain food security.

The results showed that nutritional value of tepary beans is not enough to balance concerns about its adaptability to climate stresses, particularly in areas where climate-resilient traits are prioritized over nutritional content. Results also show that other means of income make farmers less likely to perceive climate-resilient beans positively. The statistically significant negative relationship between access to extension services and smallholder farmers perceptions showed that smallholder farmers having access to information does not guarantee positive perceptions. This means that available extension programs might not be aligned with the needs of smallholder farmers who are growing climate-resilient legumes.

In conclusion, both the hypotheses of the study were rejected as the results showed that there was difference in the level of knowledge and perceptions of smallholder farmers on climate-resilient legumes and socio-economic factors do influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans. Policymakers could create training programmes that accommodate all smallholder farmers despite the size of their land. Extension services should be improved to cater for the challenges and needs of smallholder farmers.

Key words: Tepary beans, Climate-resilient legumes, Perceptions, Knowledge

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LIST OF ABBREVIATIONS AND ACRONYMS

BLR	Binary Logistic Regression
DAFF	Department of Agriculture, Forestry and Fisheries
FAO	Food and Agriculture Organization
IAEA	International Atomic Energy Agency
MLR	Multinomial Logistic Regression
SPSS	Statistical Package for the Social Sciences
StatsSA	Statistics South Africa
TREC	Turfloop Research Ethics committee
US	United States
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The National Geographic (2022) stated that climate change affects access to water for everyone around the world, resulting in more serious droughts and floods. Smallholder farmers located in countries that are not developed are the ones mostly faced with the increasing challenges due to the consequences of changes in climate on agricultural efficiency and food security. Increasing global temperatures are one of the key reasons for this problem. Climate change affects the water cycle by changing where, when, and how much precipitation falls (Grover, 2015). The shortages of water and droughts in the years 1981/1984, 1988/1989, 1991/92, 2004/2005 and in 2014/2015 seasons negatively impacted crops and livestock, thus food security and the cost of living in general (Mpandeli *et al*., 2015).

The International Atomic Energy Agency (IAEA) stated that climate change is a huge menace to global food security, environmental growth, and elimination of poverty (Mugambiwa and Tirivangasi, 2017). Furthermore, climate change causes more natural disasters and environmental problems, making it hard to grow food, and thus affecting food security. The Food and Agriculture Organisation (FAO) statistical book as stated in Herforth *et al*. (2020) stated that medium or serious food insecurity is extremely higher in Africa than in anywhere else globally and affected majority of the population in 2019. FAO as stated in Dutta *et al.* (2015) also mentioned that food security, which includes accessibility, availability, use, and stability of the food, is non-discriminatory, without geographical boundaries and ensures the right to enough, safe, healthy, and favoured food. Dutta *et al.* (2015) proposed that, with an increasing global population, households need to react to the results of climate change that cannot be avoided, such as changing the types of crops they farm. Therefore, farming climate-resilient and versatile crops is needed and tepary beans are among such crops (Ledbetter, 2022).

According to Beebe *et al*. (2013), one of the most important ways to decrease crop failures and increase food security in bean-growing areas amidst of climate change is to produce drought-improved bean cultivars. The dry subtropical slopes of the arid regions of Mexico and the southwest US are home to tepary beans (*Phaseolus acutifolius A. Gray*), which are very tolerant of drought stress (Njoki, 2014). Among the world's most drought-tolerant legume crops are these beans. These beans are believed to be the solution to food insecurity, especially for disadvantaged smallholder farmers due to their characteristics. Hence, tepary beans had been recognised not only for their high protein content and resistance to biotic and abiotic stresses, but also for their suitability for cultivation by resource-poor farmers in southern Africa (Nong *et al*., 2023).

Tepary beans can help the soil fix nitrogen, just like cowpeas and guar. Tepary bean is a self-pollinating diploid legume crop that offers food and nutrition safety mainly for farmers in villages with limited resources in sub-Saharan Africa (Mwale *et al*., 2020). Additionally, these beans are known to be resistant to illnesses and pests like bean weevil, which is brought on by *Acanthoscelides obtectus* (Jiménez *et al*., 2017). Moreover, Tepary beans are a far more drought-tolerant crop than regular beans (Mwale *et al*., 2020). This makes them a valuable genetic resource for food and for improving the genetics of related legumes. Regardless of the benefits of tepary beans for smallholder farmers, there is not enough understanding of farmers' knowledge and perceptions regarding these climate-resilient legumes. Investigating smallholder farmers' knowledge, and perceptions towards tepary beans is needed for promoting their uptake and mainstreaming them into agricultural systems. Moreover, understanding the socio-economic factors influencing farmers' decisions to adopt or reject tepary beans is critical for designing targeted interventions and policy support measures to improve their resilience and sustainability.

For these reasons and the benefits that this crop has to offer to developing countries such as South Africa that are characterised by relatively high household food insecurity that is likely to rise under changing climate, it becomes relevant to investigate smallholder farmers' knowledge on climate-resilient crops like tepary beans. This will afford these countries an opportunity to explore the prospects of crops such as tepary beans in dealing with the prevalent problems of households' food insecurity and climate change related impacts. The study will provide insights into the farmers' knowledge and perceptions as factors shaping farmers' adoption decisions and inform strategies for promoting the uptake of climate-resilient legumes in smallholder farming communities.

1.2 PROBLEM STATEMENT

The populace of the world is projected to grow by one-third by the year 2050 and developing nations will experience the biggest increases (Pariatamby *et al*., 2014). FAO (2016) anticipated that agricultural production will therefore have to increase by 60% to meet the anticipated increase in demand for food if current income and consumption growth trends continue unchanged. Nonetheless, agriculture and food security are affected by severe weather occurrences and a rise in the unpredictability of weather patterns (Senyolo *et al*., 2021), which has reduced farmers' productivity and revenue in vulnerable places. The effects of heat and drought on crop productivity put food security in danger (Nelson *et al*., 2010). For these reasons, agriculture must undertake a considerable change to reduce poverty and ensure economic prosperity while also feeding an expanding global population (Serbanescu, 2016). This task will be constrained by climate change and exploring climate-smart agricultural technologies and practices such as planting climate-resilient crops provide a good opportunity to deal with challenges related to climate change whilst safeguarding food security (Senyolo *et al*., 2018; Senyolo *et al*., 2021).

Hummel *et al.* (2018) mentioned that the evolution of drought-tolerant bean cultivars is a critical strategy for minimising crop failure and improving food security in the regions that grow beans in the surface of climate change. Konvalina (2016) stated that tepary beans are becoming increasingly popular legume crops in Africa, but their production is currently disadvantaged by a lack of improved varieties and limited access to seed and extension services. Tepary bean is under researched in South Africa (Nong et al., 2023), and it becomes very difficult for smallholder farmers in the villages to know about it, given that they already lack access to extension services. Hence, the crop has remained under-utilised despite its potential as major field crop (Nong *et al*., 2023). The knowledge about these climate-resilient legumes could assist farmers in maintaining bean production and, thus, food security. Tepary beans also serve as hay or fodder for animals and have been used as a summer cover crop that can withstand drought while soil moisture is still present (Wolf, 2018). Additionally, tepary beans have a higher nutritional value than cowpeas and guar and can be used as feed by cattle or eaten as beans by people (Ledbetter, 2022). Several studies that investigated bean varieties including tepary beans and their benefits amidst climate change challenges have been conducted from agronomic and breeding perspectives (Wolf, 2018; Mwale *et al*., 2020). A knowledge gap remains in understanding smallholder farmers' knowledge and perceptions on climate-resilient crops such as tepary beans. This study sought to fill this knowledge gap by analysing smallholder farmers' knowledge and perceptions on tepary beans and the factors influencing such knowledge and perceptions.

1.3 RATIONALE

Over the years, research has largely ignored and neglected high protein leguminous crops like tepary beans as minor crops. Yet, legumes have the potential as food security crops and it would be beneficial to include them in the adaptive strategies to enhance smallholder farmers' resilience to climate change (Jiri and Mafongoya, 2016). Legumes are drought-tolerant crops and therefore, need to be included within the adaptation strategies related to climate change (Senyolo *et al*., 2018; Senyolo *et al*., 2021). Tepary beans are better than other beans (Mwale *et al*., 2020) and have an improved abiotic stress tolerance compared to ordinary beans (Suarez *et al*., 2022). Legumes offer farmers the chance to increase their income and enhance their quality of life by opening market opportunities (Weil, 2015). Additionally, tepary beans will allow smallholder farmers to continue with their production despite changes in the climate due to their resistance to biotic and abiotic stresses (Nong *et al*., 2023). This is needed to prevent hunger and malnutrition, especially in villages where smallholder farmers are struggling and have limited resources. As a result, the utilisation of legumes that are drought-tolerant in agriculture, such as tepary beans, has the capacity to guarantee sufficient food and nutrition security for households.

Amongst the major consequence of climate change is an increase in hunger and food insecurity (Kumar *et al.,* 2018). The demand of food globally is predicted to increase by

35% to 56% between 2010 and 2050, whereas the number of people in danger of starving is expected to change by -91% to +8% throughout that time (van Dijk *et al*., 2021). Tepary beans could be a good alternative for enhancing food security, especially in areas where climate change-related challenges like drought have become a limiting factor. Crops such as tepary beans could assist in increasing the variety of crops that can be grown under changing climates (Jiri *et al*., 2017). The production of the common bean is being challenged by a changing climate together with an increase in pests and illnesses, which might negatively affect households' access to food and nutrition (Nchanji *et al*., 2021). Hence, understanding smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans and the determinants of such knowledge and perceptions is necessary and could contribute to possible solutions to help smallholder farmers withstand climate change challenges. The outcomes of the study will also help identify key determinants of such knowledge and perceptions, which can add to the literature and give indication regarding adoption of climate-resilient crops.

Acevedo *et al*. (2020) stated that smallholder farmers will likely adopt climate-resilient crops if they are knowledgeable about them and their benefits and if their perception is positive. Climate risks and market uncertainty frequently expose smallholder farmers to economic vulnerability. Therefore, understanding smallholder farmers' knowledge could be a first step to participate in climate change discussions and to inform the next necessary steps for interventions related to climate-smart agriculture to improve adaptation efforts and improve households' food security. The information obtained from this study has the prospect of informing stakeholders and policymakers concerned with enhancing food security in the midst of changing climate to make informed and targeted interventions. Furthermore, the proposed study would contribute to the existing body of knowledge on the subject and will provide key lessons and awareness for further investigations on the contributions of tepary beans towards food security and climate change adaptation to policy makers, researchers, and practitioners.

1.4 SCOPE OF THE STUDY

1.4.1 Aim

To investigate factors that influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in selected villages of Limpopo Province, South Africa.

1.4.2 Objectives

i. To profile the socio-economic characteristics of smallholder farmers in selected villages of Limpopo Province, South Africa.

ii. To assess smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province, South Africa.

iii. To describe the typologies of different legume crops that smallholder farmers are knowledgeable about and those that they are planting, including challenges associated with planting these crops.

iv. To analyse the socio-economic factors influencing smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province, South Africa.

1.4.3 Hypotheses

i. There is no difference in the level of knowledge and perceptions of smallholder farmers on climate-resilient legumes in the study area.

ii. Socio-economic factors do not influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in the selected areas of Limpopo Province.

1.5 OUTLINE OF THE STUDY

The study comprised 6 Chapters. Chapter 1 constitutes the introduction, which outlined the background of the study, problem statement, motivation for undertaking the study, aim, specific objectives and hypotheses that guided the study. Key principles in the current study are described in Chapter 2, which also studies prior research in related topics. Chapter 3 describes the methodology and analytical procedures used in conducting the current study. It comprises an outline of the research area, data sources and sampling methods as well as the analytical techniques used in the study. Chapter 4 presents the results and discussion of Descriptive Statistics results. Chapter 5 contains the Inferential Statistics results and their discussion. In Chapter 6, the results of the study are summarised, conclusion is drawn from the findings presented and the recommendations built on the results are presented.

CHAPTER 2: REVIEW OF LITERATURE

2.1 INTRODUCTION

The prior research that has been done in the same field as the current study is discussed in this chapter. This is important to lay a foundation of the current study whilst also presenting an opportunity to reflect on the existing body of knowledge to better understand methods employed and variables considered. Thus, the chapter reviews relevant literature on smallholder farmers' knowledge and perceptions on climate-resilient legumes to get a better understanding of important variables of interest and how these variables have behaved. Within this chapter, socio-economic characteristics influencing smallholder farmers' knowledge and perceptions on climate-resilient legumes and methods used are documented and this informed the choice of independent variables for the current study. The organisation of this chapter includes definition of main terminology used in the study. It also includes the literature on the effects of climate change on smallholder farming and smallholder farmers' adaptation approaches to climate change. The influence that tepary beans as climate-resilient legumes have on food security is also discussed, as well as the knowledge and perceptions of smallholder farmers on legumes. The chapter is concluded with a summary.

2.2 DEFINITION OF TERMS

2.2.1 *Smallholder farmers*

A smallholder farmer is considered a family farmer since he/she depends on family members' labour to fulfil production demands, and they normally preserve a portion of their harvest for their consumption (Knight, 2022). Department of Agriculture, Forestry and Fisheries (2012) defined smallholders as farmers who reside in their homelands and grow one- or two-income crops on small plots of land, mostly using family labour. The current study uses the definition of Cousins (2010) who defined a smallholder as a producer who sells products for money as a supplement to other sources of income, regularly market a surplus after their consumption needs have been met and are small-scale commercial farmers, with a primary focus on production for the market.

2.2.2 *Perception*

Longman Dictionary of Contemporary English explains perception as the way one thinks about something and idea of what it is like or the natural ability to understand things. McDonald (2012) defined perception as a uniquely individualised experience. Perception also refers to an opinion made on a matter or point on reception of a stimulus (Schiff, 1970). This study used the definition of Schiff (1970) in which smallholder farmers' views and opinions on subsistence farming were investigated to establish whether their perception was negative or positive.

2.2.3 *Climate-resilient*

The ability of social, economic, and ecological systems to survive hazardous occurrence, trend, or disruption is known as climate resilience (Portner *et al*., 2022). Climate resilience was defined by Grasham *et al*. (2021) as the ability to resist or lessen exposure to shocks caused by climate change, like floods and droughts. This study used the same concept.

2.2.4 *Tepary beans*

Tepary bean is said to be a desert legume native to the southwestern United States, Texas, New Mexico, and Mexico (Brink and Belay, 2006). Wolf (2018) defined it as a native, annual legume. According to Porch *et al*. (2017) Tepary bean is a nutrition dense legume crop appropriate for cultivation within resource-poor farming systems.

2.2.5 *Climate change*

Climate change is the shift in the Earth's climate caused by air variations as well as the relationships among other earth system elements that are geologic, chemical, biological, and geographic (Häfker *et al*., 2023). However, this study adopted the definition of Butts and Adams (2020) who defined climate change as a change in the usual weather found in a place. These authors continued to say that this could be a shift in how much rain a location usually receives in a year or a shift in the average temperature of a place over the course of a month or season (Butts and Adams, 2020).

2.3 CLIMATE CHANGE IMPACT ON SMALLHOLDER FARMING

Climate change's effects on smallholder farming is profound and complex (Frost *et al*., 2023). Smallholder farmers who rely on rain-fed agriculture and have inadequate resources to adapt, are mostly at risk of being affected by climatic changes (Makondo *et al*., 2014). Otto (2020) stated that climate change leads to irregular weather patterns, including irregular rainfall, droughts, floods, and heatwaves. These alterations disrupt traditional farming calendars, making it hard for smallholders to plan their planting and harvesting schedules effectively (Ndlovu *et al*., 2020). Crop production can be directly impacted by variations in temperature and precipitation patterns (Högy *et al*., 2013). For instance, increased temperatures may cause heat stress in crops, while irregular patterns of rainfall can result in water shortages or excess water, both of which can affect yield (Senyolo *et al*., 2018).

Although there are some consequences of climate change on agriculture generally, the most disadvantaged smallholder farmers in the villages are most negatively impacted. In the Central Rift Valley of Ethiopia, Belay *et al*. (2017) used interviews, focus groups discussion, and household surveys to investigate how smallholder farmers were adapting to climate change and the factors that influenced their choices. The study discovered that drought and an increase in pests and illnesses are caused by climate change, which has a detrimental impact on crop and livestock productivity (Belay *et al*., 2017). Furthermore, direct observations in the same study made during the data collection showed that the rainy season that is usually used for cultivation of some crops passed without any cultivation activity. Furthermore, the crops on the farms that made it through the prolonged drought were physiologically weaker. This resulted in the productivity of main crops decreasing gradually over the years in the study area Belay *et al*. (2017).Kaganzi *et al*. (2021) stated that Sub-Saharan Africa is among the region’s most vulnerable to the effects of climate change since most of the smallholder farmers depend on rain-fed agriculture for their economic performances. Schipper (2020) mentioned that climate change can improve or worsen the conditions for growing certain crops in certain regions. It can also lead to longer growing seasons, allowing farmers to plant more crop cycles. It also contributes to the surplus of crop-damaging pests. Heavy precipitation may be seen to be good when smallholder farmers are facing a water crisis or droughts, but in reality, it more often leads to flash flooding (Dąbrowska *et al*., 2023). This washes away topsoil and increases soil nutrients runoff and consequently, disadvantaging the farmers.

Smallholder farmers, especially in villages, need to find approaches to alleviate and adjust to the harmful impacts caused by climate change. Lybbert and Sumner (2012) mentioned that smallholder farmers can either adopt to new technologies, which are often too expensive and are usually afforded by commercial farmers or choose alternative crops which can adapt to climate changes. Harvey *et al*. (2018) reviewed the effects of and response to climate change among smallholder farmers in Central America. The authors found that 95% of the sampled smallholder farmers experienced the effects of climate change, with the majority of them not coping with the consequences of crop yields, pest and disease occurrence, revenue creation, and food security are all impacted by temperatures, erratic rainfall, and extreme weather events.

Climate change is a menace to the agriculture industry, and smallholder farmers in poor nations have limited capacity to react (Jamshidi *et al.*,2020). Etana *et al*. (2021) added that the cumulative impacts of climate change on smallholder farming can lead to loss of livelihoods and forced migration. Farmers may struggle to adjust to changing conditions, leading to more poverty and food insecurity, specifically in rural communities where agriculture is the core source of income.

Makuvaro *et al*. (2018) sought to learn more about smallholder farmers' adaptation plans and their views on how climate change would impact agricultural productivity. Findings of the study revealed that according to farmers, climate change lowers food yields and makes poverty worse (Makuvaro *et al*., 2018). It is essential for smallholder farmers to know and be alert of the challenges of climate change as this will assist them consider adaptation strategies. Therefore, in the next subsection, a reflection on smallholder adaptation’s strategies from previous studies is presented.

2.4 SMALLHOLDER FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE

Adjusting the agricultural sector to the negative impacts of climate change is crucial to preserving the lives of those who depend on it directly (Asfaw *et al*., 2016). Kurukulasuriya and Rosenthal (2013) stated that farmers have adjusted to shifting social, economic, and environmental conditions throughout human history on the one hand. On the other hand, Jones *et al*. (2012) said that it is unclear if farmers will be able to handle the accelerated rate of climate change in the years to come.

Juana *et al*. (2013) stated that being informed of or knowledgeable about climate change is necessary before adjusting to its negative impacts. Farmers resort to different strategies and mechanisms to deal with climate change. Smallholder farmers, especially those situated in regions with significant natural hazards or rainfall fluctuation are often categorized using livelihood techniques developed to decrease general sensitivity to climatic shocks and to manage their effects after they have occurred. Farmers in sub-Saharan Africa have adapted to climate change by digging more boreholes in drier areas, switching to off-farm sources of income, and reducing the quantity of livestock by killing, selling, and replacing them during extended droughts (Gandure *et al*., 2012). These strategies do not favour all smallholder farmers as they are costly. Senyolo *et al*. (2018) investigated the drivers and hindrances to adoption of climate-smart agriculture technologies in Limpopo Province of South Africa. These authors further noted that climate-smart agricultural technologies such conservation agriculture, rainwater harvesting, and early-maturing, drought-tolerant seed varieties might be the most suitable for smallholder farmers (Senyolo *et al*., 2018).

Water conservation techniques like crop irrigation, wastewater reuse in agriculture, and water harvesting have been developed by farmers in Southern Africa and parts of East Africa, where the majority of countries face water scarcity (Gandure *et al*., 2012). Most of the smallholder farmers at the Central Rift Valley of Ethiopia cannot use some adaptation strategies because of certain limitations like inadequate irrigation potential, a lack of climatic forecasting data, lack of contact with extension workers, exposure to mass media, lack of required farm resources, low level of education, and lack of finances (Gandure *et* *al*., 2012). That is why it is important to be informed about the knowledge that smallholder farmers have on certain alternative and adaptive measures and how they perceive them.

Talanow *et al*. (2021) investigated how farmers perceive climate change, factors that influence their adaptive behavior and adaptation strategies they apply in their farming practices, and whether these are medium to long-term or short-term coping strategies. These authors found that most farmers have employed adaptive strategies on their farms, which include changes in soil and crop management, such as changes of harvest and planting time, crop rotations and water conservation techniques. The current strategies these farmers have employed are mostly technological and address direct impacts of climate stressors, although climate change impacts go beyond the farm scale into society (Talanow *et al*., 2021).

Thinda *et al*. (2020) did a study on understanding the adoption of climate change adaptation strategies among smallholder farmers, based on the evidence from land reform beneficiaries in South Africa. The variables influencing farmers' adoption of adaptation techniques and the degree of adoption at the household level in South Africa were estimated using a zero-inflated Double Hurdle Model. Beneficiaries of land reform in South Africa adopted climate change adaptation strategies largely influenced by a variety of socioeconomic factors, including gender, age, and crop farming experience, as well as institutional factors, such as access to extension services and information about climate change. Based on the results, Thinda *et al*. (2020) concluded that the money farmers earned from non-farm jobs can be reinvested in agricultural operations, such as planting improved plant varieties, conserving water and soil, insurance, among other measures, to reduce climatic variability and boost output.

To analyse how small-scale farmers employed adaptation strategies in response to climate change and determinants of small-scale households’ choices of coping and adaptation approach to climate variability and change, Kom *et al*. (2020) conducted a study in Vhembe District, South Africa. Multinominal Logit Model was used, and 224 local farmers were surveyed. The results showed that climate information, gender, farm size, education level, farmer experience, decreasing rainfall, and rising temperatures were the main factors influencing farmers' decisions about how to adapt to climate change. However, the choice of coping and adaptation strategy for climate change was not significantly influenced by age, headed households, or off-farm resources.

Adaptation to climate change has been shown to be a successful method for managing its hazards, but smallholder farmers must consider several factors before making the decision. Due to their individual needs and capabilities, farmers' methods of adapting to climate change frequently vary from household to household. The factors that influence smallholder farmers' climate change adaptation measures, as well as their impact on household food security were explored by Ogundeji (2022). Ogundeji (2022) found that using improved crop varieties as an adaptation method is the most utilized adaptation measure, with approximately 47% of agricultural households in the study area adopting it. Additionally, farmers change their planting dates to align with shifts in the patterns of climatic factors, especially temperature and rainfall. They do this by using information from agricultural extension agents, metrological agencies, or their own extensive experience.

In 2018, Harvey *et al*. did a study on climate change impacts and adaptation among smallholder farmers in Central America. They discovered that, out of 860 smallholder farmers surveyed, 46.1% had modified their farming methods in response to climate change. Smallholder farmers in that study used various adaptation strategies, such as agroforestry, restoration, agroecology, intensification, and new crop varieties and technology. Other adaptation practices to climate change were to apply using more pesticides, herbicides, and fungicides, implementing soil and water conservation practices, and using more fertilizers (Harvey *et al*., 2018). Additional specific adaptation methods implemented by basic grain producers were the adoption of soil and water conservation practices and modifying agricultural schedules.

According to Senyolo *et al*. (2021), adoption is impacted both directly and indirectly by factors like age, gender, and marital status; economic factors like income, assets, and education; and networks like farmer organisations, which affect farmers' perceptions, knowledge, and familiarity with technologies. Affordability, local availability, land size, access to production financing, preferences and attitudes, gender, marital status, and pertinent training and demonstration are some of the elements that impact farmers' adoption decisions (Kinyangi, 2014). Particularly in rural areas where agriculture is the only source of income, smallholder farmers' inability to adjust to changing conditions increases poverty and food insecurity.

Smallholder farmers encounter obstacles when it comes to adopting technology because of things like imperfect property rights, a lack of information on adaptation options, and difficulty obtaining insurance or loans (Asfaw *et al*., 2016). Consequently, such farmers frequently lack access to the necessary technologies, technical know-how, and financial resources to adapt to climate change. To increase the resilience of smallholder farming systems, it is crucial to invest in climate-resilient agricultural practices, such as agroforestry, water conservation methods, and drought-resistant crops (Senyolo *et al*., 2018).

Smallholder farmers sampled by Harvey *et al*. (2018) stated that they have needs in order to safeguard adaption. They mentioned that they need provision of fertilizers and agrochemicals, technical support, training, and financial assistance from the governments, agricultural research centres, and other institutions to help them adapt to climate change. Many previous studies show that smallholder farmers’ adaptation to climate change are mostly affected by the socio-economic factors, knowledge, and perceptions (Kinyangi, 2014; Senyolo *et al*., 2018). They tend to have strategies when they have certain knowledge and perception. Hence it is important to investigate their knowledge and perception on climate-resilient legumes.

2.5 THE IMPACT OF TEPARY BEANS ON FOOD SECURITY AS CLIMATE-RESILIENT LEGUMES

Smallholder farmers produce most of the food in Asia and Africa, and, surprisingly, they are the most affected by food insecurity (Sibhatu and Qaim, 2017). According to Wiggins and Keats (2013), there are more than 450 million smallholder farms that exist in most developing countries that belong to more than two billion farmers, which include half the world's starving people and most people living in food poverty. The most significant effects of climate change, including drought and heat stress, are felt most acutely by smallholder farmers in developing nations (Morton, 2007). Climate variability, extreme weather events, and changing precipitation patterns are threatening traditional agricultural practices and disrupting crop yields worldwide. In response, researchers and policymakers are turning towards climate-resilient crops like tepary beans as potential solutions to alleviate food insecurity. This literature review, therefore, aims to explore the impact of tepary beans on food security as climate-resilient legumes.

Mafongoya and Jiri (2016) mentioned that in sub-Saharan Africa, tepary beans are mostly cultivated under poor soil conditions and low farm input systems. These authors discovered that tepary beans were the earliest mature crop among all the legumes in their study, which sought to compare the agronomic performance of tepary beans versus frequently produced grain legumes (Jiri and Mafongoya, 2016). Other commonly used legumes, including cowpea, Bambara groundnut, groundnut, and pigeon pea, were compared with tepary beans. Of all the legumes, tepary beans reached maturity the earliest, 54 days after planting. This study proved that tepary beans' early maturity would also be an advantage to farmers. The quality of tepary beans to be resilient to drought and heat stress could help smallholder farmers maintain food security within the villages in times of little or no rainfall.

In 2022, the World Health Organization (WHO) stated that increasing the cost of food commodities was a major factor in the additional 30 million individuals experiencing food insecurity in low-income countries. In Sub-Saharan Africa, South Asia, and Southeast Asia, where agricultural households are extremely poor and vulnerable, there exist those who are most at danger from crop failures and starvation caused by climate change. About 21% of the value of maize and soybean output was in areas experiencing extreme drought in 2012, which resulted in significant crop losses in the United States of America (Johnston, 2014). Food security is directly impacted by certain crops' inability to survive the effects of climate change. Therefore, cultivating climate-resilient crops is crucial to mitigating the adverse impacts of climate change.

The main reason tepary beans are farmed is for their mature, dry seeds, which are then boiled, steamed, fried, or baked. They are frequently combined with whole-grain maize and used in soups and stews. Before being added to soup, the dried seeds are often cooked and then coarsely pulverized in Uganda. They are occasionally consumed as bean sprouts or green beans. Although the leaves are rougher and require more time to cook than those of the common bean (*Phaseolus vulgaris L*.), they are nevertheless regarded as edible in Malawi. Tepary beans are not only climate change resistant, but they are also rich in carbohydrates and protein (23–25%) (Albala, 2017). These characteristics carried by tepary beans are important in maintaining food security through providing good nutrition, which is the challenge in many developing countries such as South Africa.

In Zimbabwe, a little is known about tepary beans other than the fact that a limited number of smallholder farmers in the country's east produce them for subsistence (Jackson, 2022). If a lot of smallholder farmers in developing countries were knowledgeable about these beans and their characteristics, they would contribute to reducing food insecurity. Tepary beans have shown themselves to be valuable and adaptable crops in the face of growing climate change stress in southern Africa. Tepary beans have been recognized as significant grain legume crops (Small, 2014) and has been recommended as a suitable dry season crop for the tropics.

Uebersax *et al*. (2023) in their review study on dry beans noted them as an essential factor of sustainable agriculture and food security. According to them, dry beans' natural production characteristics significantly support food security and global sustainability in both high-intensity agriculture and low-impact subsistence agricultural systems. Dry beans exhibit reduced postharvest losses and store much more easily and effectively than many other crops. (Uebersax *et al*., 2023). This is because dry beans' high levels of protein, fibre, bioactive substances, and energy make them very helpful for improving one's diet. Furthermore, tepary beans have been demonstrated to help alleviate several global food production and environmental concerns, such as more effective land use, increased crop yields, and fewer postharvest losses.

Tepary beans could be a good alternative for food security, especially in areas where drought has become a limiting factor. This is because compared to conventional crops, tepary beans require minimal irrigation, reducing pressure on water resources in arid and semiarid regions (Uebersax *et al*., 2023). Tepary bean seeds can harbour common bean diseases, such as bean common mosaic virus (Mwale *et al*., 2020). These disease-causing organisms may spread to commercial bean crops in the area. New bean crops that have more advantageous traits can be introduced to improve the diversity of nutrient-dense foods available in households and villages (Ojiewo *et al*., 2015).

Tepary bean contains about 24% protein content, 33% saturated fatty acids, 67% unsaturated fatty acids, 24% monosaturated fatty acids, 42% polyunsaturated fatty acids and essential mineral elements (i.e., Ca, Mg, Cu, Fe, K, Mn, S, Zn, Na) (Mwale *et al*.,2020). Also, tepary beans seeds have natural antioxidants which contribute to the reduction of many heart diseases such as diabetes mellitus, colon cancer and coronary heart disease (Jiri and Mafongoya, 2016). Tepary beans boast higher levels of protein and fibre compared to many common beans, like black or pinto beans.

Tepary beans are cheaper to produce than most legumes (Mashifane *et al*, 2024) and this makes them appropriate for the resource poor farmers in South Africa (Nong *et al*., 2023). The seed rate of tepary bean is dependent on climatic factors, type of soil, genotype, method of sowing and the cultural practices followed during cultivation. Irrigating at regular times has an important effect on colour, firmness and yield of pods and seed yield of tepary bean. Hoeing and weeding are crucial at early stages of crop growth since weeds compete with crop plants for nutrients, moisture, sunlight and space and act as secondary host for insect-pests and diseases (Rana and Jatav, 2017). Rana and Jatav (2017) mentioned that tepary beans prefer light, well-drained soils and that reasonable yields can be obtained on poor sandy soils with pH 5–7. Tepary beans do not tolerate waterlogging, and heavy clays are unsuitable. They can moderately tolerant saline and alkaline soils. These characteristics of tepary beans and production requirements are an indication that the beans can help in maintaining food security.

2.6 KNOWLEDGE AND PERCEPTIONS OF SMALLHOLDER FARMERS ON LEGUMES

Legumes play a significant role in sustainable agriculture by contributing to soil fertility, dietary diversity, and revenue production for smallholder farmers worldwide (Kebede, 2020). However, the successful approval and utilisation of legumes by smallholder farmers is determined not just by their agronomic properties, but also by farmers' knowledge and perceptions. This literature review looked at existing studies on smallholder farmers' knowledge and views of legumes, offering light on variables influencing acceptance, challenges, and potential for improving legume-based agriculture in various contexts. By bridging knowledge gaps and raising awareness of the benefits of legumes through farmer-to-farmer networks, extension services, and participatory learning techniques, smallholder farmers can be better equipped to make informed decisions and put legume-based farming systems into practice (Tanako *et al*.,2022). Perceptions of smallholder farmers play an important role in shaping farmers' behaviours and practices related to legume cultivation (Ekepu and Tirivanhu, 2016).

Among other things, individuals' traits, experiences, information, and the cultural and geographic setting in which they live all affect how they perceive things (Whitmarsh and Capstick, 2018). Whitmarsh and Capstick (2018) conducted a study on perceptions of climate change and mentioned that the United States (US) research showed an increase between 2008 and 2010 in the percentage of US citizens who did not accept climate change is happening, that there was scientific consensus about its human cause. Farmers must understand climate change in order to be willing to adopt adaptation methods (Simelton et al., 2013). In this way, farmers' perceptions of climate change influence both their planting choices and the implementation of adaptation strategies (De Matos Carlos *et al*., 2020). Therefore, it may be argued that designing and successfully implementing adaptation programs in agriculture requires an understanding of farmers' perspectives toward climate change.

The perception of smallholder farmers who directly depend on the weather tends to be more accurate than that of their counterparts (Whitmarsh and Capstick, 2018). Smallholder farmers' perceptions may also vary depending on the characteristics of the households, including the land's existing usage and the sources of income. Shibia (2010) contended that respondents' perceptions were unaffected by gender, in contrast to prior findings. This study therefore aimed to explore which socioeconomic factors influence views and how.

Life experiences also have an influence on perception. According to smallholder farmers who have experienced the direct effects of catastrophic weather events, there is a reasonable chance that they will occur again (De Matos Carlos *et al*., 2020). According to Ekepu and Tirivanhu (2016), positive perceptions of legumes, including their nutritional value, soil-improving properties, and income-generating potential, are associated with higher adoption rates among smallholder farmers. Behera and France (2016), on the other hand, stated that negative perceptions, such as concerns about labour requirements, market access, and social stigma, can be a constraint to adoption and limit the integration of legumes into farming systems. Therefore, having knowledge can influence one's perceptions.

Smallholder farmers can be encouraged to adopt legume-based agriculture through various means, even in the face of difficulties. Ojiewo *et al*. (2018) stated that legumes can be adopted more easily and contribute more to sustainable agricultural development if seed systems are strengthened, climate-resilient varieties are promoted, extension services are improved, and market access is increased. Moreover, including legumes in agroecological techniques like crop rotation and intercropping might improve soil health, biodiversity, and climate change resilience. Okiro *et al*. (2021) stated that empowering women farmers, who often play substantial roles in legume production and processing, can also contribute to inclusive and equitable agricultural development. Assisting farmers can add to their knowledge of legumes and help them have a certain perception.

2.7 CONCEPTUAL FRAMEWORK

The Figure 2.1 below shows the conceptual framework of the study.

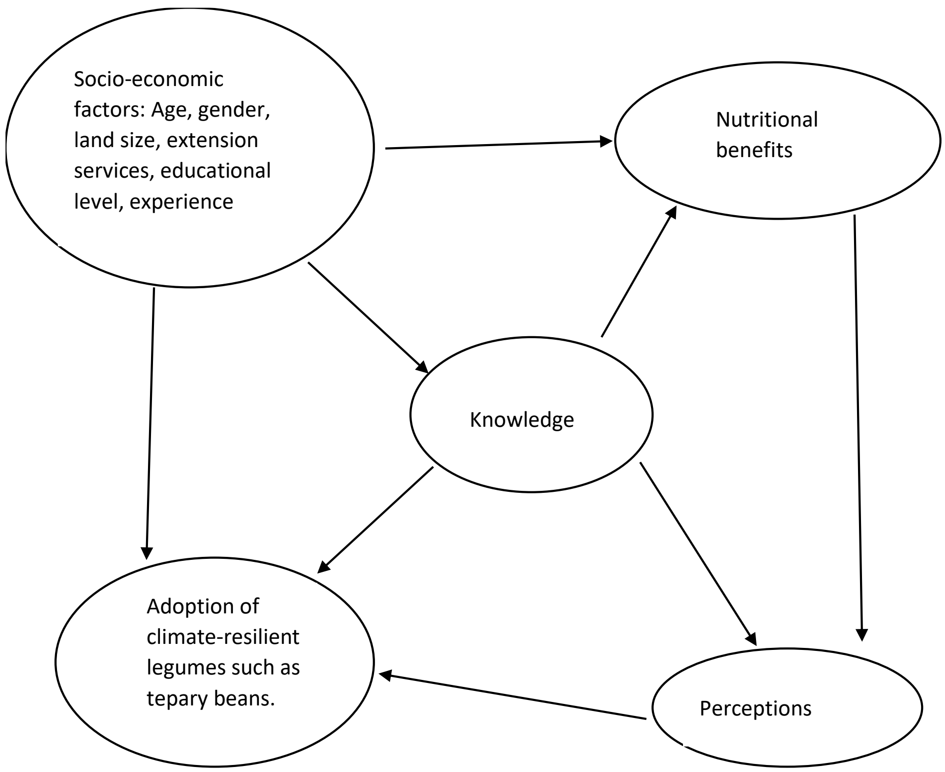

FIGURE 2. 1: CONCEPTUAL FRAMEWORK

This study aimed to investigate factors that influence smallholder farmers' knowledge are perceptions on climate-resilient legumes such as tepary bean. A conceptual framework helps to understand the relationships between factors that influence the independent variables (knowledge and perceptions).

Knowledge involves an understanding of the resilience characteristics of tepary beans, such as their drought resistance, nutritional benefits, and specific cultivation practices (Parker *et al*.,2022). It also involves awareness of climate change impacts and sustainable agricultural techniques. Perceptions refer to the attitudes and beliefs (Wesely, 2021) that farmers hold about these beans, including their perceived benefits (e.g., higher yield, improved soil health) and challenges such as access to the market, labour demands, and financial costs). Both knowledge and perceptions are crucial factors that determine whether farmers adopt and sustain the use of tepary beans.

The knowledge and perceptions are varied and interconnected. Adoption of tepary beans is directly influenced by both knowledge and perceptions. Koundinya *et al*, (2018) said that farmers who are well-informed about the benefits and cultivation methods are more likely to adopt them into their farming systems. Furthermore, access to extension services plays a significant role in this adoption process. Extension services provide smallholder farmers with the required training, resources, and guidance to better understand and implement best practices for growing climate-resilient crops like tepary beans.

Another critical dependent variable is the production of tepary beans, which depends not only on knowledge and perceptions, but also on practical factors such as experience in farming and the land size available. While conducting a study on the impact of land fragmentation, farm size, land ownership and crop diversity on profit and efficiency of irrigated farms, Manjunatha *et al*. (2013) concluded that experienced farmers with larger land sizes may have the resources to experiment with new crops, while smaller-scale farmers might face constraints. Education level is another key demographic factor influencing both knowledge and perception. Higher levels of education often correlate with better understanding and adoption of innovative agricultural practices.

Nutrition is another dependent variable of interest, as the cultivation of tepary beans may contribute to improved food security and dietary diversity. The economic benefits of growing tepary beans, including marketability and profitability, could influence farmers' decisions to continue production. Additional moderating factors include access to financial resources, social networks such as the influence of community leaders or farmers' groups, and government policies that might promote or hinder the adoption of climate-resilient agricultural practices.

This framework sought to understand the dynamics between farmers' knowledge, their perceptions, and the broader socio-economic characteristics that influence the adoption and successful cultivation of tepary beans in villages, with a focus on climate resilience and food security. It also highlighted how these variables can possibly improve agricultural practices, increase production, and contribute to better nutrition and long-term sustainability.

2.8 SUMMARY

First, the key terminology employed in the current study were specified in this chapter. The literature on how climate change is affecting smallholder farming was then looked at, and it was found that smallholder farmers, who mainly depend on rain-fed agriculture, face serious difficulties as a result of climate change. Since the climate is changing, smallholder farmers must adjust. The adaptation techniques of smallholder farmers to climate change were also examined in this chapter. A variety of adaptation techniques are used by smallholder farmers to deal with climate change. Lack of funding, access to technology, and insufficient support services, however, restrict many of these approaches.

The literature on the impact of tepary beans on food security presented a promising solution for smallholder farmers struggling with climate-induced agricultural challenges. Despite their potential, tepary beans remain underutilized by smallholder farmers, partly due to limited awareness and knowledge about their characteristics. Lastly the chapter looked at the knowledge and perceptions of smallholder farmers on legumes. Positive perceptions, particularly regarding the nutritional and soil-improving benefits of legumes, encourage adoption. However, challenges like limited resources, no access to extension services and labour requirements can limit the integration of these crops into traditional farming systems. While the literature highlights the effects of climate change on smallholder farming and various adaptation strategies, there is a gap in research regarding the knowledge and perceptions of smallholder farmers towards climate-resilient legumes like tepary beans. Additionally, socio-economic factors influencing farmers' knowledge and perceptions remain underexplored.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

The chapter comprise the methodology followed in conducting this current study. The chapter is then divided into three smaller sections: the study area, data sources and sampling strategies, and analysis methodologies.

3.2 AREA OF THE STUDY

Limpopo Province was identified as one of the provinces with the large percentage (16%) of agricultural households on a national scale (StatsSA, 2016). Census of Commercial Agriculture stated that 79% of farming land in Limpopo is owned by farmers, which is higher than the national average of 77% (StatsSA, 2020). Cowling (2023) also stated that in 2021 the province was recorded as the one having larger portions of rural areas (35.2%), thus higher percentage of agricultural activities, including smallholder farming. This province recorded the highest percentage (25%) in the production of crops. According to Maponya *et al*. (2014), understanding and evaluating the situation of smallholder farmers is essential to ensuring food security, creating jobs, and lowering poverty. In the province of the Limpopo, farmers are the foundation of many economies.

The province consists of five districts. The Capricorn District is one of the province's districts where the study was carried out. Located between the northwest regions and the Kruger National Park, as well as between Gauteng and the northern parts of Limpopo, is Capricorn District. Encompassing 21705 km2, it serves as a gateway to Botswana, Zimbabwe, and Mozambique (StatsSA, 2011). Figure 1 shows the map of Capricorn District and its municipalities. Agriculture is one of the major economic sectors in Capricorn District and the statistics show that there are many smallholder farmers in the district. Capricorn District has a population of 1 447 103, with 427 174 households (StatsSA, 2023). It has the third-largest district economy in the province and is mainly rural in nature. The majority of the land in the district is suitable for arable agriculture, specifically for crops, cattle, vegetables, grains, and pastures.

FIGURE 3. 1: MAP OF LIMPOPO PROVINCE SOUTH AFRICA

Source: Google maps

The figure 3.1 above is the map showing different districts found in Limpopo Province, which is found in South Africa.

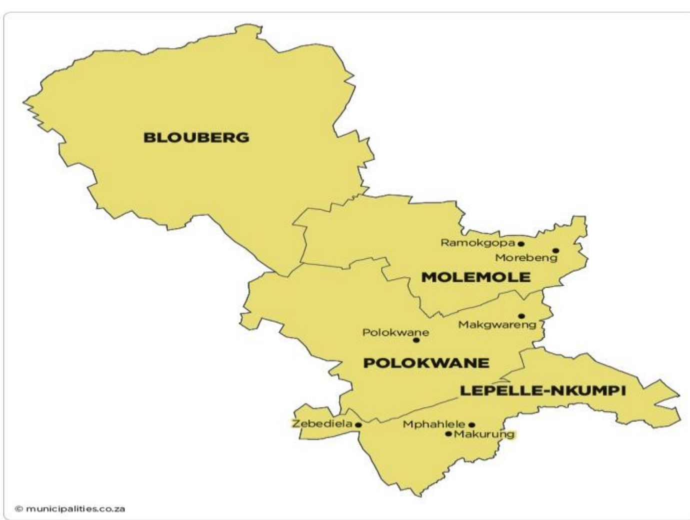

FIGURE 3. 2: MAP OF CAPRICORN DISTRICT

Source: Google maps, municipalities.co.za

Figure 3.2 above shows Capricorn District, and four municipalities found in it. The study was conducted in different villages within Capricorn District. The villages were selected with the assistance of extension officers.

3.3 DATA SOURCES AND SAMPLING METHODS

Primary data was used in the study, which combined quantitative and qualitative methods. Data that can be coded in a numerical form was collected through quantitative research (Vogt *et al*., 2014). It involved statistics, and the raw data were numbers. Additionally, according to Vogt *et al*. (2014), qualitative research collects non-numerical, free-form data through questionnaires, interviews, and observations that are not coded using a numerical system. The qualitative data used in this study came from examining specific situations to learn more about smallholder farmers' detailed knowledge and perceptions regarding climate-resilient legumes.

Structured questionnaires and in-person interviews with smallholder farmers were used to gather primary data. Purposive sampling was employed in the study to choose study participants. The purposive sampling technique is a deliberate choice of a participant due to the qualities the participant possesses (Etikan *et al*., 2016). In this study, smallholder legume farmers from the selected villages were targeted.

The formula below was used to calculate the sample size.

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

Whereby:

n is the sample size

N is the number of smallholder farmers

e is the level of significance

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

$$n = \frac{41\,867}{1+41867(0.1)^2}$$

$$n = 99{,}76 = 100$$

Therefore, 100 was the estimated sample size. The 10% significance was used in this study. A 10% significance level corresponds to a 90% confidence level. This means the study is 90% confident that the true population parameter lies within the calculated range of the sample estimates.

Table 3.1 below shows the number of respondents from each selected villages of Limpopo province.

TABLE 3. 1 NUMBER OF RESPONDENTS PER VILLAGE

Village	**Number of respondents**
Thabakgone	16
Mamotintane	3
Ga-Motholo	4
Bloodriver	3
Ga-Thoka	4
Tjiane	36
Botlokwa (Mphakane)	11
Ga-Phasha	9
Ga-Kobe	14
TOTAL	**100**

Source: Author compilation from Data (2024).

Table 3.1 above shows the number of smallholder farmers per villages. The extension officers, through Department of Agriculture, assisted in getting the most smallholder farmers for the study.

3.4 ANALYTICAL TECHNIQUES

Descriptive statistics was used to address objective one, which was to profile the socio-economic characteristics of smallholder farmers in selected villages of Limpopo Province. When conducting research, it is crucial to compute Descriptive statistics first. In addition to other sorts of variables like nominal, ordinal, interval, and ratio, Descriptive statistics also includes measures of frequency, central tendency, distribution or deviation, and place (Kaur a*t al*., 2018). Furthermore, Descriptive statistics was also used to address objective three, which was to describe the different typologies of various legume crops that smallholder farmers in the study area were knowledgeable about and those that they were planting, including challenges associated with planting these crops.

In order to address objectives two, the study used Descriptive statistics by employing the Likert scale. Likert scale tool was used to gather the information on the dependent variable. The information was used to generate the dependent variables for the fourth objective. Likert scale is referred to as a set of statements offered for a real or theoretical situation under study. Participants were asked to rate how much they agreed or disagreed with the statement on a metric scale. Singh (2006). Therefore, in a few settlements in the province of Limpopo, the knowledge and opinions of smallholder farmers about climate-resilient legumes, namely tepary beans, were evaluated using a Likert scale. A five-point rating system was utilized in the study. The assertions were presented to the respondents, who were asked if they strongly agreed, agreed, disagreed, or were not sure. A five-point Likert scale is important to use because it reduces likelihood of response bias in that it allows respondents to choose the midpoint option if they lack strong opinion on the topic or are unsure (Lam and Green, 2019).

To analyse the socio-economic factors influencing smallholder farmers' knowledge on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province, Multinomial Logistic Regression (MLR) model was used. According to Bhattacharjee *et al*. (2022), when applied to a response variable that has more than two levels, MLR is a linear logistic regression extension. It is applied to an exploratory variable that contains two or more unsorted categories. By contrasting it with the reference category, each model forecasts how predictors will affect the likelihood of success in that category. Each model has its own set of regression coefficients and intercepts. One of the main advantages of Multinomial Logistic Regression is that it provides highly interpretable coefficients that quantify the relationship between features and outcome variable. There are not many other models that provide this level of interpretability for multiclass outcomes. Multinomial logistic regression is a more flexible model than Ordinal Logistic Regression.

The following model was used:

$\log = \frac{Pr(y=j)}{Pr(y=j\prime)}$= α+$\beta_1X_1$+ β_2X_2+…+ β_kX_k +……………………………….equation 1

where:

j = (knowledge of smallholder farmers)

α =intercept

β_1= estimated parameters

X_1= various independent variables

Specific model:

$$\log = \frac{Pr(low\ knowledge)}{Pr(high\ knowledge)} = B0 + X1Lsize + X2Hsize + X3Elevel + X4Aext + X5Exp + \mathrm{X6Gen} + \mathrm{X7Age} + \mathrm{X8Empl} + X9Mstat + X10Prodc + X11Nutv + \mathrm{e}$$

$$log = \frac{Pr(medium\ knowledge)}{Pr(high\ knowledge)} = B0 + X1Lsize + X2Hsize + X3Elevel + X4Aext + X5Exp + X6Gen + X7Age + X8Empl + X9Mstat + X10Prodc + X11Butv + e$$

To analyse the socio-economic factors influencing smallholder farmers' perceptions on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province, Binary Logistic Regression (BLR) model was used. The BLR is non-linear estimation where the dependent variable is dichotomous, taking the value of 0 or 1. The BLR model terms are suitable to the study, where the results of the model are dichotomous (Ali *et al*., 2016). The information on the dependent variable for this objective was gathered using a Likert scale, which is a set of statements provided for an actual or hypothetical circumstance under examination. This model helped understand the important factors that influence the smallholder farmers' perceptions.

Below is the general model that was used:

The general model: $Li = Ln\left(\frac{Pi}{1-Pi}\right) = B0 + BiXi + \cdots + BnXn + e$ ………………equation 2

Where:

Yi= dependent variable (smallholder farmers' perception on tepary beans)

P= probability that smallholder farmers have perceptions about tepary beans

1-P= probability that smallholder farmers do not have perceptions about tepary beans

B_0= intercept

B_i= estimated parameters

X_i= various independent variables

e= error term

The specific model is expressed as follows:

$$\text{Smallholder farmer}s\ p\text{erceptions on tepary beans } (Y) = \text{B0} + \text{X1Lsize} + \text{X2Hsize} + \text{X3Elevel} + X4Aext + X5Exp + X6Gen + X7Age + X8Empl + X9Mstat + X10Prod + X11Nutv + X12Legm + e$$

Table 3.2 below shows variables for Multinomial Logistic Regression (MLR) and Binary Logistic Regression (BLR) models, their description and unit of measurement for analysing the socio-economic factors influencing smallholder farmers' knowledge on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province.

TABLE 3. 2 VARIABLES FOR MLR AND BLR, THEIR ABBREVIATIONS, DECRIPTIONS AND MEASUREMENTS

Variables	**Abbreviations**	**Description of variables**	**Units of measurement**
Dependent variables			

Y Smallholder farmers knowledge of tepary beans		High =3, medium=2, or low=1	Categorical
Y Smallholder farmers perception of tepary beans		1 if perception is positive, 0 otherwise	Dummy
Independent variables			
X1 Land size	LSIZE	Size of arable land	Hectares
X2 Household size	HSIZE	Number of household members	Numeric
X3 Educational level	ELEVEL	1=No formal education 2=Primary education 3=Secondary education 4=Tertiary education	Categorical
X4 Access to extension	AEXT	1 if the respondent has access to extension, 0 otherwise	Dummy
X5 Experience in crop farming	EXP	Number of years in farming	Years
X6 Gender	GEN	1 if the respondent is male, 0 otherwise	Dummy
X7 Age	AGE	Actual age of household head	Years
X8 Employment	EMPL	1 if the respondent is employed, 0 otherwise	Dummy
X9 Marital status	MSTAT	1 if single 2 if married 3 if widow/er 4 if divorced	Categorical
X10 Production cost of tepary beans	PRODC	1 if high production cost 2 if not sure 3 if low production cost	Categorical
X11 Nutritional value	NUTV	1 if high nutritional value 2 if not sure 3 if low nutritional value	Categorical

X12 Legumes farmers crops	LEGM	1 if the farmer knows 1-3 legumes 2 if the farmer knows 4 and above	Categorical

Source: Author compilation

Table 3.3 below shows how knowledge and perception as independent variables were measured on a five-point Likert scale.

TABLE 3. 3 TABLE OF DEPENDENT VARIABLES AND THEIR MEASUREMENTS

Variable	Unit of measurement	Sources
Knowledge	5-point Likert scale. Strongly agree and agree were considered to be highly knowledgeable, not sure, medium knowledgeable whilst disagree and strongly disagree were considered having the low knowledge.	(Ong and Sui Pheng, 2021); (Friedman and Shepeard, 2007)
Perceptions	5-point Likert scale. Strongly agree and agree were considered to have positive perception (equated to 1). Not sure, disagree and strongly disagree were considered negative perception (equated to 0).	(Friedman and Shepeard, 2007)

3.5 QUESTIONNARE PRE-TESTING

To data collection was tested prior to actual data collection to validate the instrument. The questionnaire was first tested with 10% of the 100-sample size. The common rule of thumb for pilot testing is to take at least 10% -20% of the total sample size (Chrysos, 2017). That is, 10 smallholder legumes farmers were randomly picked to determine the reliability and validity of the questionnaire. Based on the initial responses, the questionnaire was adjusted as suggested, and some questions were rephrased based on the response of respondents to further improve the data collection instrument.

3.6 STUDY LIMITATIONS

The researcher was born in Free State and is not very fluent in Sepedi, which is the main language spoken in the study area. Not speaking a fluent language as the respondents can hinder a smooth discussion during the interview process. To address this limitation, a well-trained translator was always available throughout the data collection process to assist whenever problems of communication arose. The researcher used pictures of tepary beans and their seeds to make it simpler for the respondents to easily identify with the crop. The questionnaire was prepared in English and then translated to respective local language (i.e. Sepedi) so that the researcher can get accurate information from the smallholder farmers since this language was used by all the respondents in the area.

Although the estimated sample size of the study is considered reasonable, a larger sample size that covers a wider geographical area could further enhance the usefulness of the study outcomes in informing policymakers. This is because policymakers are members of the public and not only a district. In the current study, one district was considered due to time and financial resources. Nevertheless, a representative sampling was used, and this makes the results creditable and useful for stakeholders that may wish to take them forward.

3.7 ETHICAL CONSIDERATION

This study was conducted in line with the ethical procedures of the University of Limpopo. Thus, since the study involved human interactions, ethical approval was sought from the University of Limpopo Turfloop Ethics Committee (TREC) prior to conducting the study. See the Ethical Approval with number REC-0310111-031 in Appendix number 1 of this dissertation. Subsequently, the intention of the study was clarified clearly to the participants and consent was sort with respondents prior to commencement of the interviews. The participation of respondents was completely voluntary, and respondents were told that they could withdraw at any time if they did not feel comfortable. The data that participants submitted was kept confidential and utilized solely for this study. Only the researcher, supervisors and the university have access to the information that was shared by the respondents. The identity of all the respondents was protected so that the information they provided would not be directly traceable to them. In this way, information shared will not be traced back to individual respondents. The study also did not harm any human beings, animals, or plants in any way as there was no direct contact with them.

3.8 SUMMARY

This chapter firstly described the area of the study, which was selected areas of Limpopo Province. The study used both qualitative and quantitative data collected through structured interviews with smallholder farmers using questionnaires. Pilot testing of the questionnaires was conducted with 10 farmers to improve the questionnaire. Language barriers due to the researcher's limited fluency in Sepedi were solved by using a well-trained translator during interviews. The study followed ethical guidelines, including obtaining ethical approval and ensuring informed consent prior to commencement of the study. A purposive sampling method was employed to select 100 respondents from nine villages, targeting smallholder legume farmers in the study area. Descriptive statistics was used to address objectives one and three, which were to identify and describe the socio-economic characteristics of smallholder legume farmers and to describe the typologies of different legume crops that smallholder farmers in the study area are knowledgeable about and those that they are planting, including challenges associated with planting these crops. In order to address objectives two, the study used Descriptive statistics by employing the Likert scale. Multinomial Logistics Regression model was used to generate the results of the socio-economic factors influencing smallholder farmers' knowledge. Binary Logistics Regression model was used to generate the results of the socio-economic factors influencing smallholder farmers' perceptions on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province.

CHAPTER 4: DESRIPTIVE STATISTICS RESULTS AND DISCUSIONS

4.1 INTRODUCTION

This chapter consists of the discussions of the study results related to all the objectives of the study. Descriptive statistics was used to profile the socio-economic characteristics of smallholder farmers in selected villages of Limpopo Province, South Africa, to assess their knowledge and perceptions on climate-resilient legumes such as tepary bean in the study area and to describe the typologies of different legume crops that smallholder farmers in the study area are knowledgeable about and those that they are planting, including challenges associated with planting these crops. Therefore, in the next subsections Descriptive statistics results generated from these analytical techniques are presented and discussed in relation to the literature review.

4.2 DESRIPTIVE STATISTICS RESULTS

The Table 4.1 below shows the descriptive results for continuous variables.

4.2.1 Descriptive results for continuous variables

TABLE 4. 1 DESCRIPTIVE RESULTS FOR CONTINUOUS VARIABLES

	Experience in crop farming	**Land size (ha)**	**Respondents' age**	**Household size**
Mean	11,8	1,43	46	4,75
Minimum	0,5	0,13	25	1
Maximum	33,0	4,00	72	11
Standard deviation	7,71	1,16	13,27	2,15

Source: Survey results (2024).

From Table 4.1 above, the average experience in crop farming was 11.8 years. This suggests that on average, the smallholder farmers have a solid background in legume crop farming, which could contribute to their farming skills and productivity. The least experienced smallholder farmer in the sample had just half a year of experience, indicating that there were some very new or inexperienced smallholder farmers in the group. The most experienced smallholder farmer had 33 years of experience, showing a substantial range in farming experience among the households. The standard deviation is 7,71, indicating that there is considerable variation in experience levels.

Accumulating farming experience is only a basic form of knowledge formation. Farming experience has a positive impact as most of the farmers acquired climate change knowledge through their own experiences and understanding (Belay *et al*. 2017). Smallholder farmers with greater expertise are said to know more about climate change and how it affects farming methods. Nonetheless, in addition to the importance of climate change and farming experiences acquired throughout the years, sufficient support and technical know-how to smallholder farmers is necessary to facilitate their considerations to pursue climate-smart agricultural practices (Senyolo *et al*., 2021; Senyolo *et al*., 2023).

The average landholding size was 1.43 hectares, suggesting that most smallholder farmers in the study managed small to medium-sized plots of land. The minimum land size was as little as 0.13 hectares, which could limit their farming capacity. The maximum landholding in the sample was 4 hectares, indicating that while most smallholder farmers have small plots, a few have more substantial land resources. The standard deviation in land size is 1.16037. The standard deviation of 1.16037 hectares suggests moderate variability in land size among households. Wang *et al*. (2015) found that agricultural productivity increases with land size. Increased size of land may have a positive impact on farmers' profits.

Table 4.1 shows that the average age of smallholder farmers was 46 years, suggesting that most were middle-aged, which is typical for those in leadership or decision-making roles within households. The youngest smallholder farmer was 25 years old. The oldest smallholder farmers 72 years old, indicating that there are some elderly individuals leading households. The standard deviation is 13.27. There was a variation in the ages of smallholder farmers in the study area.

These results show that youth hardly participate in smallholder farming. This could be due to young people not having any land suitable for farming, unlike older ones. It also noted that the youth participation in agriculture reduces as the educational accomplishment increases (Agwu *et al*. 2014). Geza *et al*. (2021) also discovered that the youth have negative perceptions about agriculture's capability of improving their living standards.

It is shown in Table 4.1 that the average household size was the study area was five members. This means that most households consist of five members. The minimum household size of the respondents was one and the largest household in the sample had 11 members. Household size has the standard deviation of 2.153. According to the results of Baloch *et al*. (2022), farmers' household size was positively correlated with their choice of adaption tactics. Jiri *et al*. (2015) found that households with more people who are physically fit and capable of working in agriculture adjust more than households with fewer people. This could mean that smallholder farmers with more household members are likely to be knowledgeable about climate-resilient legumes due to more members bringing more knowledge in the households and participating in farming activities. Additionally, larger household size is important in helping farmers to have larger labour force to conduct farm-related activities (Langill *et al*. 2023). Makate *et al*. (2019) negatively associated the adoption of improved legumes with household size and positively associated with other socio-economic characteristics like distance to town and central region.

4.2.2 *Descriptive results for categorical variables*

TABLE 4. 2 DESCRIPTIVE RESULTS FOR CATEGORICAL VARIABLES

Variables	**Categories**	**Percentages (%)**
Gender of a smallholder farmer	Female	59
	Male	41
Employment status	Yes	52
	No	48
Marital status	Single	38
	Married	26
	Widow(e)r	28
	Divorced	7
Access to extension services	Yes	35
	No	65

Educational level	No formal education	10
	Primary education	18
	Secondary education	47
	Tertiary education	25
Production costs of tepary beans	High production costs	17
	Not sure	24
	Low production costs	59
Nutritional value of tepary beans	High nutritional value	50
	Not sure	27
	Low nutritional value	23
Legumes that smallholder farmers grow	Grows 1 to 3 legumes grows	7
	Grows 4 and above legumes	93

Source: Survey results (2024)

Table 4.2 above shows the gender distribution of smallholder farmers in the area. Women dominated most farming operations in the research area, as evidenced by the fact that 59% of all respondents were female smallholder farmers. Fourteen percent of the respondents are male heads of smallholder farms. Jost *et al*. (2016) found that men are in metropolitan regions seeking alternative employment, whereas women are more likely to participate in smallholder farming because it is typically performed in rural areas. These findings are in line with their findings. This could also be due to the majority of women being single or widowed and must provide for their families. Other studies like that of Conradie *et al*. (2023) and McKinley (2016) observed no significant relationship between gender and environmental behaviour. McKinley (2016) even suggested that future climate change studies should put more emphasis on spatial considerations and access to climate change information and less emphasis on gender issues.

Table 4.2 illustrates the employment status of smallholder farmers in the study area. Fifty two percent (52%) of smallholder farmers were not employed and 48% were employed. This indicates that a slightly larger proportion of those farmers were not employed compared to those who were employed. The results align with those of authors such as Falola and Achem (2017), who discovered that smallholder farmers are frequently retired and elderly, hence being officially unemployed. Unemployed smallholder farmers who have ventured into farming are likely to have more knowledge as they spend most of their time farming.

Table 4.2 displays the marital status of smallholder farmers in the study area. About 39% of these smallholder farmers were single, making this the most common marital status, 28% were widowed, 26% were married and 7% were divorced. Kimaro *et al.* (2015) stated that married farmers are expected to take part in agricultural activities than unmarried ones because they have more family responsibilities.

Smallholder farmers in the study area were asked if they had access to extension services. Of the sampled farmers, 65% did not have access to extension services, whereas only 35% did. This indicates that initiatives or programs designed to offer resources, information, and help are available to the minority of smallholder farmers. Giving farmers information about new technologies they may utilize to increase productivity, incomes, and their standard of living, extension services play a crucial role in African development (Msuya *et al*., 2017).

Smallholder farmers in the research area's educational attainment is seen in Table 4.2 above. Only 10% of smallholder farmers had no formal education, while the majority (47%) had secondary education, 25% had university education, and 18% had only primary education. According to Mussa (2015), a lack of centralized decision-making in farming is indicated by the lack of influence of average education. Most smallholder farmers who lack formal education are probably ignorant about climate-resilient legumes. It is commonly accepted that farmers with more education possess greater expertise and are more inclined to participate in agricultural initiatives. Hu *et al*. (2022) pointed out that farmers with greater educational attainment could be more inclined to embrace agricultural initiatives. This means that most of the smallholder legume farmers in the study are likely to adopt to climate-resilient legume crops. Tafesse *et al*. (2015) argue that educated farmers might take part in non-agricultural activities as they have broad skills and knowledge of other sectors, diverting their attention away from knowing about the adoption of agricultural adaptations, which in this study is the use of climate-resilient legumes.

The results above show the distribution of responses regarding the perceived production cost of tepary beans. The majority of respondents, 59%, believed that the production cost of tepary beans were low. This suggests that many view tepary beans as an economically feasible crop. About 24% of respondents were not sure about the production cost. A smaller percentage of smallholder farmers, 17%, consider the production cost to be high. High production costs discourage farmers from adopting new agricultural practices (Roesch-McNally *et al*., 2018). In this case, the minority think that tepary beans as expensive to produce.

It has been shown in Table 4.2 that the largest percentage, 50%, of smallholder farmers believe that tepary beans have high nutritional value, highlighting their recognition as a nutritious food source. About 27% of respondents were unsure about the nutritional value of tepary beans. This could mean that there is a knowledge gap among smallholder farmers regarding the health benefits of this crop. About 23% of smallholder farmers think that tepary beans have low nutritional value. Porch *et al*. (2017) said that tepary beans are a very nutritious legume crop with the range of composition and cooking characteristics. Smallholder farmers who have knowledge about the nutritional value of tepary beans are likely to perceive them positively and adopt to them.

Table 4.2 shows the of the legumes grown by smallholder farmers of tepary beans. The largest percentage, 93%, of smallholder farmers grow four and above legumes, The minority of 7% grow 1 to 3 legumes. This could mean that farmers are aware of most legumes. The legumes farmers mentioned included tepary beans, soybeans, lentils, cowpea, chickpeas, green beans, groundnuts, peas and sugar beans. Soybeans lead legume crop production globally, followed by peanuts, dry beans, dry peas, chickpea, cowpea, fava bean and lentils (Semba, 2021). The legumes grown by smallholder farmers in the study area are amongst the most grown legumes in the world.

The Table 4.3 below shows the Likert-scale results for smallholder farmers' knowledge on climate resilient legumes.

TABLE 4. 3 : LIKERT SCALE RESULTS FOR SMALLHOLDER FARMERS' KNOWLEDGE

Statement	Strongly agree	Agree	Not sure	Disagree	Strongly disagree	Decision
I have knowledge of tepary beans.	19	35	14	25	7	High knowledge
I know climate-resilient legume crops.	25	66	9	0	0	High knowledge
I know any tepary beans characteristics and benefits.	23	25	20	23	9	High knowledge
The unavailability of resources limits the type of crops grown.	75	25	0	0	0	High knowledge
I think tepary beans can help maintain food security in the households.	28	23	42	7	0	High knowledge
I think tepary beans can help limit the effects of climate change such as droughts, erratic rainfall, and high temperatures.	24	24	44	7	1	High knowledge
I have received information related to legumes in the last six months.	7	24	0	45	24	No knowledge
I have received information related to climate change in the last six months.	16	29	0	33	22	No knowledge

Source: Survey results (2024)

Table 4.3 above shows the results for smallholder farmers' knowledge on climate-resilient legumes on a 5-point Likert scale. The results show the level of knowledge farmers have by their level of agreement or disagreement with the given statements. The study measured the knowledge looking at Ong and Sui Peng (2021)'s decision rule in which strongly agree and agree are considered to be highly knowledgeable, not sure being medium knowledgeable whilst disagree and strongly disagree means having no knowledge. The results were interpreted by combining the percentages of agree with strongly agree, also disagree, and strongly disagree. Not sure showed that respondents neither agreed nor disagreed with the given statements.

Although 91% of respondents knew legume crops that can tolerate drought, high temperatures, or that can grow when rainfall is not enough, only 54% had high knowledge of what tepary beans are. Smallholder farmers knew other legume crops including groundnuts and soybeans, among others. Only 48% of them knew any tepary beans characteristics and benefits. The majority of smallholder farmers in the study area had not received any information related to climate-resilient legumes and climate change in the last six months. This could be due to the lack of extension services as the results Table 4.2 showed that only 35% of the respondents had access to extension services. The overall results on Table 4.3 above (6 out of 8 statements) show that most of smallholder farmers in the study had high knowledge of climate-resilient legumes. This may be due to the fact that smallholder farmers depend on their experience over the years to gain knowledge about legumes (Belay *et al*. 2017).

4.2.3 Smallholder farmers' perceptions

The Table 4.4 below shows the Likert-scale results for smallholder farmers' perceptions on climate resilient legumes

TABLE 4. 4: LIKERT SCALE RESULTS FOR SMALLHOLDER FARMERS' PERCEPTIONS

Statement	**Strongly agree**	**Agree**	**Not sure**	**Disagree**	**Strongly disagree**	**Decision: Positive (1) or Negative (0) perception**
Climate-resilient crops help save money that we use to purchase food.	35	57	8	0	0	1

Climate-resilient crops help in reducing food insecurity.	33	57	10	0	0	1
The department of agriculture offers the needed support to smallholder farmers.	4	34	17	29	16	0
I have received information related to legumes in the last six months.	7	24	1	43	25	0
I have received information related to climate change in the last six months.	14	30	2	31	23	0
I am satisfied with the quality of the crops I am producing	14	57	4	24	1	1
I am satisfied with the quantity of the crops I am producing.	9	52	3	35	1	1
I have knowledge of climate-resilient crops.	22	68	5	5	0	1
Producing my own crops is better than buying them.	48	40	2	10	0	1
I would advise other smallholder farmers to grow climate-resilient crops	44	46	8	2	0	1

I prefer tepary beans over other beans.	11,0	16	20	40	13	0

Source: Survey results (2024)

Table 4.4 above shows the results for smallholder farmers' perceptions on climate-resilient legumes on a 5-point Likert scale indicating their level of agreement and disagreement with the given statements. The study measured the perception looking at Friedman and Shepeard (2007)'s decision rule in which strongly agree and agree are considered to have positive perception towards climate-resilient legumes. Not sure, disagree and strongly disagree are considered to have negative perception towards climate-resilient legume. The results were interpreted by combining the percentages of agree with strongly agree (equating them to 1), and also not sure, disagree and strongly disagree equating them to 0).

About 92% of smallholder farmers believed that climate-resilient crops would help save money used to purchase food and 90% believed that the crops would help reduce food insecurity. This is considered a positive perception towards climate-resilient legume crops. Most smallholder farmers were satisfied with the quality and quantity of the crops they produce. However, 88% of them mentioned that producing their own crops is much better than buying them and therefore advised other smallholder farmers to grow climate-resilient crops. Although the majority of farmers knew tepary bean, only 27% of them preferred them over other legumes. This could mean that being highly knowledgeable does not guarantee positive perception. Out of 11 statements, 7 show positive perception towards climate-resilient legumes. Assefa *et al*. (2008) noted that farmers' perceptions could be a restriction to improved quality and high production. Bryan *et al*. (2009) pointed out that farmers' perceptions of climate change are dependent on their recent and past experiences. This applies to this study because 56% of the respondents have not received any information related to climate change in the last six months. This suggests that if smallholder farmers do not positively perceive climate-resilient legumes and are less likely to be willing to adapt, and consequently their productivity will decline. Farmers with more acquired climatic knowledge will have a stronger awareness of the relationship between climate change and variable consequences, as well as necessary practices that they might take as adaptation and mitigation techniques (Härtel and Pearman, 2010).

4.2.4 Typologies of different legume crops

The Table 4.5 below shows the results of the different types of legumes smallholder farmers in the study area know and grow.

TABLE 4. 5: LEGUMES KNOWN AND GROWN BY SMALLHOLDER FARMERS

	Tepary beans	**Soybean**	**Groundnut**	**Cowpea**	**Other**
Which legumes do you know?	54%	97%	100%	98%	87%
Which legumes do you grow	24%	12%	32%	34%	50%

Source: Survey results (2024)

Table 4.5 above shows the legume crops known and grown by smallholder farmers and the percentage of farmers growing them in the study area. About 54% of respondents knew tepary beans, but only 24% grew them. This could be due to lack of resources since the majority of smallholder farmers mentioned that they lack resources. The most known legume crop in the study area was groundnut, followed by cowpea and soybean. Other legumes crops known and grown by smallholder farmers included lentils and other varieties of beans such as green beans, sugar beans, red beans and chickpea.

TABLE 4. 6: CHARACTERISTICS OF DIFFERENT LEGUMES CROPS

	Tepary beans	**Soybean**	**Groundnut**	**Cowpea**
Drought and heat tolerant.	47%	7%	80%	87%
Requires a lot of water for growth.		66%	2%	1%
Affected mostly by pests and diseases		83%	34%	19%
High nutritional value	75%	67%	69%	37%
Long shelf-life	100%	40%	27%	62%
Low-cost production	97%	15%	65%	90%

Source: Survey results (2024)

Table 4.6 above shows different legume crops, and their specific characteristics recognised by smallholder farmers in the study area. Smallholder farmers were asked to say which characteristic(s) apply to each crop based on their knowledge and experiences. About 47% of respondents were of the view that tepary beans are drought tolerant. None of the smallholder farmers believed that tepary beans require a lot of water for growth or are affected mostly by pests and diseases. This suggests that in their experiences of growing tepary beans, smallholder farmers did not struggle during less or no rain seasons and have never had to deal with diseases and pests affecting tepary beans. This could be helpful to many resource-poor farmers who usually lacks irrigation and capital to purchase inputs such as agrochemicals or pesticides. About 75% of the respondents believe that tepary beans have high nutritional value, meaning they contain essential nutrients that fulfill the body's needs for energy, growth, and repair. This trait is important when considering food and nutrients security of households or individuals. All the respondents who know tepary beans said they have a long shelf life. This means that tepary beans can be stored for a long time after harvest and would still be in good conditions. Ninety-seven percent (97%) of smallholder farmers said tepary beans have a low-cost production. These characteristics suggest that tepary beans are suitable for maintaining and augmenting food security.

Soybeans were said not to be drought and heat tolerant, required a lot of water for growth and mostly affected by pests and diseases. Although 67% of the respondents believed that soybeans have high nutritional value, 40% of them mentioned that they have long shelf-life and only 15% of them believed the cost production is low. The 15% minority that believed the cost production of soybeans is low might be the ones who can afford all the resources needed to grow soybeans. Groundnut and cowpea were also believed to be drought and heat tolerant. Groundnuts were said to have high nutritional value by 67% of the respondents and 65% stated that they cost low to produce. Cowpea is also said to have longer shelf life and to have a low-cost production.

The Table 4.7 shows the challenges that smallholder farmers in the study area face when growing legume crops.

Table 4. 7: Challenges smallholder farmers face

Challenges	Frequencies (%)
Water scarcity/drought	59
Crops get eaten by animals	13
Crop theft	9
Pests and diseases	39
Empty promises from Department of Agriculture	73
No access to extension services	65
No access to the market	67
Lack of resources/input	51
Poor quality produce sometimes	29

Source: Survey results (2024)

Table 4.7 above shows that about 59% of smallholder famers in selected villages of Limpopo Province mentioned that changes in climate change led to some periods of drought. This made farming difficult as there was also not enough water from the taps for irrigation. Without reliable water sources or irrigation systems, farmers are often forced to rely on inconsistent rainfall. This limits their crop choices, reduces yields, and makes them vulnerable to crop failure during dry periods. Some smallholder farmers (13%) said that they frequently lose crops to wildlife, or even livestock. This is caused by the lack fencing, leading to crop losses that impact their income and food security.

Very few (9%) smallholder farmers mentioned crop theft as another persistent problem for them as they have limited security measures. They said that crop theft mostly happens in the field. Smallholder farmers said that crop theft leads to financial instability and reduces their confidence in expanding their production. Pests and diseases were also listed as one of the biggest problems by 39% of the respondents. They damage crops, especially when farmers lack the means to buy effective pesticides or access to pest-resistant crop varieties. Some smallholder farmers lack advice on handling pest and disease outbreaks, worsening the problem. About 73% of smallholder farmers in the study area said they often face unfulfilled promises from local agricultural departments, such as promised fundings, equipment, or training that never happens. This lack of support leaves farmers without essential resources and knowledge, hindering their productivity and growth. A majority (65%) of smallholder farmers, as shown in Table 4.2, lack access to extension services, leaving them without valuable insights to improve their practices.

Smallholder farmers often face difficulties in reaching profitable markets, such as long distances, poor infrastructure, or a lack of knowledge about pricing and demand. Without direct market access, farmers often sell through agents who offer lower prices, reducing their profits. Access to quality seeds, fertilizers, pesticides, and tools is often limited for smallholder farmers. This lack of input affects both yield quantity and quality, with smallholder farmers producing lower amounts of poorer-quality crops that fetch lower prices.

4.3 SUMMARY

This chapter presented the results of the Descriptive statistics and their discussions, which was used to profile the socio-economic characteristics of smallholder farmers, to assess smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean, and to describe the typologies of different legume crops that smallholder farmers in the study area are knowledgeable about and those that they are planting, including challenges associated with planting these crops in selected villages of Limpopo Province, South Africa. Likert scale results for the second objective in this study, were also presented and discussed in this chapter whereby smallholder farmers showed their level of agreements or disagreements with the given statements. Furthermore, this chapter described the typologies of different legume crops, their characteristics that smallholder farmers are knowledgeable about and those that they are planting. Challenges associated with planting of these crops were also reported.

CHAPTER 5: INFERENTIAL STATISTICS RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

The study's discussions and conclusions from Inferential statistics are presented in this chapter. The models used in the analysis were Multinomial Logistic Regression (MLR) model for knowledge and Binary Logistic Regression (BLR) for perceptions. In order to analyse the socioeconomic factors influencing smallholder farmers' knowledge of climate-resilient legumes like tepary beans in the research area, the MLR model was used. Finally, the socioeconomic factors influencing smallholder farmers' perceptions of climate-resilient legumes, specifically tepary beans, in the study area were investigated using the BLR model. IBM Statistical Package for the Social Sciences (SPSS) was used to analyse the socioeconomic factors influencing smallholder farmers' perceptions and understanding of climate-resilient legumes, specifically tepary beans, in a few settlements in the Limpopo Province of South Africa. The results generated from these analytical techniques are also presented and discussed in relation to the literature review.

5.2 MULTINOMIAL LOGISTIC REGRESSION RESULTS

The Table 5.1 below shows the goodness-of-fit for Multinomial Logistic Regression results.

TABLE 5. 1: MODEL FITTING

	Model fitting criteria	**Likelihood ratio tests**		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Final	46,41	148,11	22	<,001

Source: Survey results, SPSS (2024)

A model's goodness-of-fit can be evaluated using the -2 Log Likelihood (D'Agostino, 2017). According to Table 5.1, the final model's -2 Log Likelihood value is 46,412. The resulting model shows a considerable improvement in fit over the null model, as indicated by the chi-square statistic of 148,108. There are twenty-two Degrees of freedom (df). The likelihood ratio test is highly statistically significant, as indicated by the significance value

<.001 in Table 5.1 above. This implies that compared to the null model, the final model with its independent variables is a notable improvement. This indicates that the independent variables that were incorporated into the final model are likely to contribute to the explanation of the variance in the outcome variable.

Table 5.2 below is the Pseudo R-square of the model. Pseudo R-square shows the Cox and Snell, Nagelkerke and McFadden values.

TABLE 5. 2 MEASURES OF PSEUDO R-SQUARE

Pseudo R-square	
Cox and Snell	0,773
Nagelkerke	0,901
McFadden	0,761

Source: Survey results, SPSS (2024)

Thus, Table 5.2 above shows the Cox and Snell R-Square value of 0.773, which means that about 77.3% of the variance in the dependent variable is explained by the model, which indicates a good model fit. A high Cox and Snell R-Square value suggests that the model is explaining a significant portion of the variance in the outcome. The high Nagelkerke value of 0.901 shown above suggests that the model explains approximately 90.1% of the variance, indicating an excellent fit. The McFadden R-Square compares the likelihood of the fitted model to a model with no independent variables. Values between 0.2 to 0.4 are considered indicative of a good fit, so 0.761 suggests an extremely well-fitting model. A McFadden R-Square of 0.761 confirms that the model has a high explanatory power and fits the data very well.

The Table 5.3 below shows the parameter estimates on Multinomial Logistic Regression. comparing two groups (Medium knowledge and No knowledge) against the reference group, High knowledge.

TABLE 5. 3: PARAMETER ESTIMATES OF MLR MODEL

Independent variables	Medium knowledge					No knowledge			
	B	**Std. Error**	**Wald**	**Sig.**		**B**	**Std. Error**	**Wald**	**Sig.**
Intercept	-4,081	14,683	,077	,781		-20,419	16,621	1,509	,219
Experience in crop farming	-,241	,221	1,186	,276		-,259	,259si	,999	,317
Employment status	5,736	3,314	2,996	,083*		4,971	3,502	2,015	,156
Production cost of tepary beans	-3,728	2,205	2,857	,091*		-5,216	2,305	5,122	,024**
Gender	-3,550	2,773	1,639	,201		-2,589	3,046	,723	,395
Nutritional value of tepary beans	6,368	3,125	4,152	,042**		10,469	3,489	9,003	,003***
Household size	-,101	,551	,034	,855		-,058	,647	,008	,929
Age	,058	,132	,194	,660		,084	,149	,314	,575
Educational level	-1,804	1,761	1,050	,306		-,867	1,873	,214	,643
Access to extension services	2,865	3,023	,899	,343		4,395	3,372	1,698	,193
Marital status	-,078	,735	,011	,916		1,376	1,037	1,759	,185
Land size in hectares	,776	,803	,935	,334		1,848	1,009	3,352	,067*
a. The reference category is: **High knowledge**									
Note: ***, **, and * are significant at 1%, 5%, and 10% significant levels, respectively									
a. This reduced model is equivalent to the final model because omitting the effect does not increase the Degrees of Freedom.									

Source: Survey results (2024)

Table 5.3 above illustrates the BLR model results of the study. The positive coefficient value indicates a positive relationship between the independent variables and the dependent variable while a negative value indicates a negative relationship. The standard error measures the variability of the coefficient estimate. Wald is a test statistic used to assess the significance of each variable. The significance suggests that the variable has a meaningful contribution to the dependent variable. Six of the twelve independent variables in the study were revealed to be significant. Three of the six significant factors that were identified were determined to be favourably significant, while the remaining three were found to be negatively significant. Considering the significant levels of 1%, 5%, and 10%, the model's findings show that there was a statistically significant association between the independent factors and the dependent variable. The next subsection elaborates on the significant variables.

a) Employment status of smallholder farmer

The positive coefficient of 5.736 and the significance value of 0.083 for the variable representing the employment status of smallholder farmers with medium knowledge highlight a positive relationship between employment and knowledge of climate-resilient legumes. It implies that, on average, being employed is associated with an increase in the knowledge of climate-resilient legumes among farmers classified as having medium knowledge. This could mean that employment status of smallholder farmer provides access to additional resources, networks, or information that help them gain knowledge about climate-resilient farming practices. For example, employed smallholder farmers might participate in training programs, which may expose them to advanced farming techniques, including the use of climate-resilient legumes.

Employment status often influences the accessibility and adoption of agricultural knowledge. Brooks *et al*. (2013) did a study on agriculture as a sector of opportunity for young people in Africa and found out that individuals with stable employment or various means of income are more likely to access and apply new agricultural technologies, as they have more resources to invest in learning. Gatzweiler and von Braun (2016**)** mentioned that medium knowledge often fills the gap between low and high adoption rates, particularly in area where formal education is limited. Specific to climate-resilient beans, Wheeler and von Braun (2013) highlighted the importance of targeted knowledge dissemination in their study on climate adaptation in agriculture. Authors highlighted farmers with medium knowledge, sustained by good employment status, can act as mediators, sharing visions with less knowledgeable farmers while adopting practices themselves (Wheeler and von Braun, 2013). This dynamic might explain the positive relationship in the present in the current study.

b) Production cost of tepary beans (medium knowledge)

The negative coefficient of -3.728 and the significance value of 0.093 for the variable representing the production cost of tepary beans with medium knowledge highlight a negative relationship between employment and knowledge of climate-resilient legumes. Jack (2013) stated that high production costs often discourage farmers from adopting innovative practices, especially when resources are limited. This negative relationship is in line with the results of Meijer *et al.* (2015) in their study of the role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. The authors highlighted that high input costs can reduce the farmers' willingness to invest in gaining and applying new knowledge about crops, especially under medium knowledge levels where the farmers are aware but may lack confidence or resources for full adoption (Meijer *et al.*, 2015). This explains the negative coefficient (-3.728), suggesting that as production costs rise, medium knowledge may become less impactful.

c) Production cost of tepary beans (no knowledge)

Production cost of tepary bean also has significance of 0.024 with a coefficient value of -5.216 for no knowledge. Smallholder farmers facing higher production costs or who believes costs are high may allocate less time and resources to learning or exploring alternative practices. This could be due to affordability. For farmers with no knowledge, high production costs represent a significant limitation, as they may be less willing or able to invest in the initial steps of understanding and experimenting with new crops such as tepary beans. As discussed by Roesch-McNally *et al*. (2018)**,** the financial restrictions of smallholder farmers can be a major obstacle to the adoption of new crops, especially when smallholder farmers have no prior knowledge or experience with them. In the case of tepary beans, which are known for their resilience to drought and other climate stresses, but their adoption often requires upfront investments in seeds, knowledge transfer, and sometimes infrastructure. Makuvaro *et al*. (2018) and Senyolo *et al.* (2018)

emphasised that smallholders are often hesitant to invest in gaining knowledge or adaptation to such crops if the initial costs are perceived as too high. This corresponds to the findings of the present study, where the production cost of tepary beans has a significant negative impact on farmers with no knowledge of the crop.

d) Nutritional value of tepary beans (medium knowledge)

Nutritional value of tepary beans has a positive coefficient of 6.368 and the significance value of 0.042 for medium knowledge. This shows a positive relationship between nutritional value of tepary beans and knowledge of climate-resilient legumes. When new crops are tolerant to climate shocks, their nutritional advantages can be a strong encouragement for farmers to embrace them. Meijer *et al*. (2015) emphasised that farmers' willingness to try and implement new agricultural technologies can be greatly influenced by their understanding of a crop's nutritional benefits. This could explain the positive relationship observed in the current study. Medium-knowledge farmers were typically aware of new crops or agricultural techniques, but they might want more information or encouragement to fully embrace them. According to Gatzweiler and von Braun (2016), farmers are more likely to use information that highlights a crop's nutritional advantages to their farming operations later on. The significant coefficients shown above clearly show that smallholder farmers with medium levels of knowledge benefit from nutritional knowledge in terms of their general comprehension of climate-resilient crops. Knowing the nutritional value of crops like tepary beans often plays a huge role in enhancing farmer engagement with climate-resilient agriculture.

According to Banga (2014), crops considered to have a high nutritional value, such as tepary beans, provide reason for adoption since they contribute to improved food security while also offering resilience to climate-related stresses. This aligns with the study of Acevedo *et al*. (2020) who highlighted that when smallholder farmers are informed about the nutritional benefits of a climate-resilient crop, their knowledge and willingness to engage with the crop increase. According to Banga (2014), crops considered to have a high nutritional value, such as tepary beans, provide reason for adoption since they contribute to improved food security while also offering resilience to climate-related stresses.

e) Nutritional value of tepary beans (no knowledge)

Nutritional value of tepary beans is significant for no knowledge. The positive coefficient of 10.469 and significance value of 0.003 for no knowledge highlight a positive relationship between nutritional value of tepary beans and knowledge of climate-resilient legumes. If smallholder farmers have no knowledge of tepary beans, they will view them as having low nutritional value, thus are likely not to adopt to them. These results do not align with the findings of Acevedo *et al*. (2020) who stated that when smallholder farmers are knowledgeable about the nutritional benefits of a climate-resilient crop, they will be willing to engage with the crop increase. The significant relationship between nutritional knowledge and no knowledge suggests that farmers not being aware of the nutritional benefits means that they are less likely to embrace climate-resilient beans like tepary beans or that nutritional value is not the major factor they look into when deciding to grow crops.

f) Land size in hectares

Land size has a positive coefficient of 1.848 and significance value of 0.067 with no knowledge. This means that larger land size weakly increases the likelihood of no knowledge. Farmers with more land may be focusing on diverse crops, possibly allocating lesser time and effort to gaining deeper knowledge about specific legume crops like tepary beans. Similarly, Hu *at al*. (2020) concluded that farm size is positively correlated with the likelihood of adopting agricultural innovations, as larger farms have more capital to invest in new technologies. The positive coefficient of 1.848 suggests that as land size increases, smallholder farmers with no knowledge are more likely to be exposed to, and eventually acquire, knowledge about climate-resilient crops. Smallholder farmers with larger land sizes have the opportunity to experiment with new agricultural practices and climate-resilient varieties. As a result, they are more likely to gain knowledge about these innovations, including their potential environmental and economic benefits. This aligns with the positive coefficient of 1.848, suggesting that land size may provide an indirect pathway for increasing knowledge about climate-resilient beans.

5.3 BINARY LOGISTIC REGRESSION RESULTS

The Table 5.4 below shows the Omnibus tests of model coefficients that provides a statistical test to assess whether the model as a whole, provides a significant improvement in fit over a baseline model. The Omnibus test assesses whether at least one of the independent variables in the model is significantly related to the outcome variable.

TABLE 5. 4: OMNIBUS TEST OF MODEL COEFFICIENTS

		Chi-Square	df	Sig.
Step 1	**Model**	62,172	12	< ,001

Source: Survey results, SPSS (2024)

The Chi-square statistic on Table 5.4 above is shown as 62,172 and is a measure of how well the model with independent variables fits the data compared to the null model. A large Chi-square value indicates that the inclusion of independent variables significantly improves the fit of the model over the null model. A high Chi-square value (62,172) and a p-value < 0.001, helps to conclude that the model with independent variables provides a much better fit to the data than a model with no independent variables. This suggests that at least some of the independent variables in the model have a meaningful impact on the outcome. The Degrees of freedom are 12 and is associated with the number of independent variables in the model. This means that the model includes 12 independent variables being tested collectively to assess their joint significance. The significance value is less than 0.001, indicating that the test is highly statistically significant. This supports the validity of using the model, as it suggests that the independent variables included are indeed useful for predicting the outcome variable.

TABLE 5. 5: SUMMARY OF THE MODEL

Model summary			
Step	**-2 Log likelihood**	**Cox and Snell Square**	**Nagelkerke R Square**
1	54,480[a]	,463	,672

Source: Survey results, SPSS (2024)

Table 5.5 above shows the -2 Log Likelihood of 54,480, indicating the fit of the model after the first set of independent variables was included. The Cox and Snell R-Square has a value of 0.463, suggesting that about 46.3% of the variance in the outcome is explained by the model. The value of Nagelkerke R-Square is 0.672 and it implies that the model explains about 67.2% of the variance in the dependent variable.

The Table 5.6 below shows the independent variables in the Binary Logistic Regression model, which were hypothesized to influence the dependent variable (outcome being predicted). The values of coefficient (B), standard error (S.E), Wald and significance (Sig.) of the independent variables are shown.

TABLE 5. 6: RESULTS OF BLR MODEL

Variables in the Equation					
		B	**S.E.**	**Wald**	**Sig.**
Step 1[a]	**Age**	-,061	,060	1,016	,313
	Gender	,049	,818	,004	,952
	Educational level	,074	,557	,018	,894
	Nutritional value of tepary beans	-1,971	1,016	3,762	,052*
	Legumes farmers grow	-,441	,736	,359	,549
	Experience in crop farming	,037	,071	,273	,601
	Employment status	-1,978	1,143	2,995	,084*
	Production cost of tepary beans	2,548	1,507	2,858	,091*
	Household size	,041	,245	,029	,865
	Land size in hectares	1,140	,488	5,457	,019**
	Marital status	1,138	,542	4,404	,036**
	Access to extension services	-2,695	1,059	6,473	,011**
	Constant	-1,561	5,573	,078	,779
Note: ***, **, and * are significant at 1%, 5%, and 10% significant levels, respectively					

Source: Survey results (2024)

Table 5.6 above illustrates the BLR model results of the study. The coefficient represents the effect size of the variable. A positive value shows a positive relationship between the variable and the dependent variable while a negative value shows a negative relationship. The standard error measures the variability or uncertainty of the coefficient estimate. Smaller values indicate more precise estimates. Wald is a test statistic used to assess the significance of each variable. The significance suggests that the variable has a meaningful contribution to the dependent variable. The study had twelve independent variables and six of them were found to be significant. From the six identified significant variables, three variables were found to be positively significant and the other three were negatively significant.

a) ***Nutritional value of tepary beans***

Nutritional value of tepary beans had the coefficient of -1.971, which indicates a substantial negative relationship. The significance value is 0.052. This could mean that smallholder legume farmers prioritize other factors over nutritional benefits when deciding on production or consumption. Smallholder farmers' perceptions of crops are important factors influencing their adoption, and perceptions of nutritional value are often linked to these decisions. Arbuckle and Roesch-McNally (2015) stated that the perceived benefits of a crop, including nutritional value, influence farmers' adoption behaviours. Meldrum *et al*. (2018) however, noted that perceptions about a crop's resilience and its potential to grow well in specific environmental conditions are just as important as nutritional benefits. When it comes to tepary beans, smallholder farmers may acknowledge the crop's nutritional worth but may not completely see it as a practical means of improving food security in a changing climate, which could lower their assessment of the crop's capacity to withstand climate change. The coefficient of -1.971 observed here may reflect such a dynamic where farmers' perceptions of the nutritional value of tepary beans are not enough to balance concerns about its adaptability to climate stresses, particularly in areas where climate-resilient traits are prioritized over nutritional content.

b) ***Employment status of smallholder farmer***

Employment status has the coefficient value of -1.978 and the significance value of 0.084. This means that the employment status of the smallholder farmers negatively affects their perceptions towards climate-resilient legumes. Smallholder farmers working off the farm may have less time or resources to dedicate to farming activities, such as tepary bean production. These results suggest that smallholder farmers with alternative employment (e.g., off-farm employment) may perceive new crops, such as climate-resilient beans, less favourably, as they are less dependent on agriculture for their livelihoods.

The negative coefficient of -1.978 in the present study aligns with findings of Barnes *et al*. (2019), who found that smallholder farmers with alternative employment were less likely to adopt new agricultural technologies, including climate-resilient crops, due to competing interests and priorities. Off-farm employment can divert attention and resources away from farming, making these farmers less likely to invest in or perceive the benefits of climate-resilient beans, especially if their income is not only through farming.

c) ***Production cost of tepary beans***

Production cost of tepary beans has the coefficient of 2.548. This is a strong positive relationship, suggesting higher production costs positively affect the perceptions of smallholder farmers towards climate-resilient tepary beans. The significance value is 0.091. This may show that smallholder farmers who invest more in tepary bean production are getting better outcomes. The positive and marginally significant relationship between the production cost of tepary beans and smallholder farmers' perceptions of these beans as climate-resilient crops suggests that farmers are prepared to agree to higher costs if they perceive the long-term benefits of the crop in terms of climate resilience. The marginally significant effects point out the importance of framing the production cost of climate-resilient crops as an investment in the future stability of agricultural systems, particularly in the face of climate change.

Akinyi *et al*. (2022) stated that smallholder farmers might associate higher production costs with better quality or greater potential for climate resilience, seeing the crop as more worthwhile regardless of the higher input costs. This finding suggests that while cost is an important consideration, smallholder farmers may recognize the value of investing in a crop that offers long-term resilience against climate change, particularly if the perceived benefits are greater than the costs.

d) ***Land size in hectares***

The coefficient and significance values of land size that the smallholder farmers have in hectares are 1.140 and 0.019. The is a large positive relationship between land size and smallholder farmers' perceptions towards climate resilient beans. Larger land sizes are associated with a strong positive effect on the perceptions smallholder farmers have. This means that smallholder farmers with more land are better positioned to achieve positive outcomes such as higher yields, better livelihoods, or increased likelihood of growing tepary beans than those with smaller sizes of land. This might be because larger land allows for diversification, economies of scale, or increased production capacity.

The size of land has important and positive relationship with most of the adaptation strategies in farming. This means that the larger size of land, the more the probability of planting different crops and adopting to different measures (Belay *et al*. 2017) and thus increasing the knowledge of farmers. This aligns with the study of Hu *et al*. (2022), which showed that the larger sizes of land influence farmers' willingness to adopt new farming measures. Barrett *et al.* (2010) said that although it was assumed in the earlier years that increases in productivity were not correlated with larger land size; on the contrary, this may be the case. Furthermore, Robert *et al*. (2010) noted that farm size increases agricultural productivity.

e) ***Marital status***

Marital status of smallholder farmers in selected villages of Limpopo Province have a positive coefficient of 1.138 and significance value of 0.036. This strong positive relationship suggests that marital status plays a significant role in how smallholder farmers perceive climate-resilient beans. Married smallholder farmers might have more stability, shared resources, access to labour, or collaborative decision-making that improves outcomes. The current study's findings align with those of Nnadi and Akwizu (2008), who similarly concluded that marriage positively affects the level of youth involvement in rural agriculture.

The coefficient of 1.138 and significance value of 0.036 for marital status in relation to the perceptions of smallholder farmers towards climate-resilient beans suggests a positive and statistically significant relationship. This indicates that married smallholder farmers are more likely than single farmers to perceive climate-resilient beans positively. Married farmers, especially those in rural regions, frequently have easier access to family labour, which makes it easier to implement new or labour-intensive farming methods (Ndiritu *et al*., 2014). This explain why marital status is positively correlated with positive perceptions of climate-resilient beans. Married farmers have dependents and may be more inclined to adopt climate-resilient crops to ensure food security and income stability, increasing the likelihood that they will perceive the advantages of such crops positively.

f) ***Access to extension services***

The coefficient of access to extension services is -2.695 and the significance value is 0.011. This significant negative relationship indicates that access to extension services reduces the dependent variable. This could indicate inefficiencies or misalignment in the way extension services are delivered. For instance, available extension programs might not be tailored to the needs of smallholder farmers who are growing climate-resilient legumes. Smallholder farmers receiving extension services may still be struggling in other areas, such as resource limitations or poor implementation of advice. These results may also mean that even though some smallholder farmers may receive extension services, the information might not be enough. Some smallholder farmers may not be getting extension services at all but still managing to farm.

Provision of extension services is characterised by various challenges, which in some instances render the services less effective. For example, Sompranje *et al*. (2021) said that the challenges around the agricultural extension service's inability to deliver exceptional performance were due to poor financial support systems. Some farmers may behave logically, and the knowledge at their disposal may have an impact on their perceptions (Lugandu,2017). Since for the majority of developing nations, extension services are mostly provided by the government, (Berhane *et al*. 2018), South Africa included, the results show that smallholder farmers in the study area have not been getting such services and will therefore not have positive perception. Some farmers like the ones surveyed by Khan and Akram (2012) perceived extension services as ineffective. These findings further indicate that there is a need to strengthen the relationship between agricultural extension officers and farmers so as to improve the effectiveness of agricultural extension services (Khan and Akram, 2012).

5.4 INSIGNIFICANT VARIABLES

It sometimes happens that considered independent variables in a study may turn out to be insignificant in influencing the dependent variable. This could be because they do not have a strong enough relationship with the dependent variables, or that there was not enough evidence in the study area to support the relation. Furthermore, this could happen if the variable does not influence the outcome, or if the data used does not capture the variable’s effect well due to measurement errors, limited sample size, or insufficient variation. Additionally, other variables in the model might overshadow their impact, especially if they are more strongly correlated with the dependent variable. In this study such dependent variables were the smallholder farmers’ knowledge and perceptions on climate-resilient legumes. Insignificant independent variables for the MLR model were experience in crop farming, employment status (no knowledge), gender, household size, age, educational level, access to extension services, marital status and land size (medium knowledge). Lastly, insignificant independent variables for the BLR model were age, gender, educational level, legumes farmers grow, experience in crop farming and household size.

CHAPTER 6: SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter presents the summary, conclusion and recommendations related to this current study. Thus, the findings of the study on the knowledge and perceptions of smallholder farmers about climate-resilient legumes in selected villages within the province of Limpopo are summarized in this chapter. Following that, the conclusion derived from the current study's findings is given. This chapter concludes with a summary of the recommendations derived from the results.

6.2 SUMMARY

Changes in the climate have been causing increases in temperatures all over the world and smallholder farmers located in developing countries are the most affected due to the impacts this has on agricultural productivity and food security. Smallholder famers then have to find alternative ways to maintain the agricultural productivity. They first should have knowledge and perceptions on these alternative measures, which in this study is the use of climate-resilient legumes, specifically tepary bean, in order to adopt to them. This study aimed to investigate factors that influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in selected villages of Limpopo Province, South Africa. There were four specific objectives, namely: to profile the socio-economic characteristics of smallholder farmers, assess smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean, describe the typologies of different legume crops that smallholder farmers in the study area are knowledgeable about and those that they are planting, including challenges associated with planting these crops and finally, to analyse the socio-economic factors influencing smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary bean.

The literature reviewed has shown that tepary beans could be the solution for smallholder farmers to maintain food security. The study also looked at the knowledge and perceptions of smallholder farmers on legumes. Positive perceptions encourage adoption of climate-resilient legumes. Challenges like limited resources and no access to extension services can limit the integration of these crops. The literature highlighted the effects of climate change on smallholder farming and various adaptation strategies, but a gap in research regarding the knowledge and perceptions of smallholder farmers towards climate-resilient legumes like tepary beans remained. Additionally, socio-economic factors influencing farmers' knowledge and perceptions remain underexplored.

The study was conducted in selected villages of Limpopo Provinces, South Africa and used primary data. One hundred (100) smallholder legumes farmers were purposively selected and interviewed using structured questionnaires. To achieve objective one, Descriptive statistics was employed to identify and describe the socio-economic characteristics of smallholder legume farmers in selected villages on Limpopo province. According to the findings, smallholder farmers had a minimum of 0.5 years of crop-farming experience and a maximum of 33 years. This demonstrated the growing crop-farming experience of smallholder farmers. The largest piece of property was 44 hectares, while the smallest was 0.13 hectares. According to the report, the oldest smallholder farmer was 72 years old, and the smallest was only 25. The ages of smallholder farmers in the research area varied significantly. There was a minimum of one person per household and a maximum of 11. The findings reveal that 59% of smallholder farmers were women, 52% of them were unemployed, and 65% of them lacked access to extension services. These smallholder farmers were most likely to be single (39%), followed by widowed (28%), married (26%), and divorced (7%). Ten percent of smallholder farmers in the study region had no formal education, while the majority (47%) had secondary education, followed by tertiary education (25%) and primary education (18%). The majority of respondents (59%) thought that tepary beans had a low cost of production, and 50% thought that they were highly nutritious. This suggests that many smallholder farmers viewed tepary beans as an economically sufficient crop and nutritious food source. About 93% of smallholder farmers in the study areas seemed to know more than four different legumes crops. This showed that they explore and not stick to planting similar crop.

To address objectives two, the study used Descriptive statistics by employing the Likert scale. The study measured the knowledge looking at the decision rule in which strongly agree and agree are considered to be highly knowledgeable, not sure being medium knowledgeable whilst disagree and strongly disagree means having no knowledge. Most smallholder farmers were highly knowledgeable on the statements asked on the Likert scale. The perceptions of smallholder farmers were measured looking at the decision rule in which strongly agree and agree are considered to have positive perception towards climate-resilient legumes and many smallholder farmers perceived climate-resilient legumes positively.

To describe the typologies of different legume crops that smallholder farmers in the study area are knowledgeable about and those that they are planting, including challenges associated with planting these crops, the study used Descriptive statistics as well. The results showed that 54% of smallholder farmers in selected areas know tepary beans, and only 24% were growing them. Legumes crops like soybeans, groundnut and cowpea were the most known. About 47% of smallholder farmers knew tepary beans as drought and heat tolerant and 75% believed they have high nutritional value. Tepary beans were viewed as long-shelf and low-cost production legume crops. The study also investigated different challenges faced by smallholder farmers in selected villages. Water scarcity, crop theft, pest and diseases, no extension services and lack of resources were the major challenges mentioned.

Multinomial Logistics Regression model was used to generate the results of the socio-economic factors influencing smallholder farmers' knowledge on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province, South Africa. The total of six variable were found to be significant. The variables which were found to be positively significant are the employment status (0.083) for medium knowledge, production cost (0.024) for no knowledge, nutritional value for medium knowledge (0.042) and no knowledge (0.003), and land size for no knowledge (0.067). Production cost was found to be negatively significant for medium (0.093) and no knowledge (0.024).

A positive relationship between employment and knowledge of climate-resilient legumes implies that being employed is associated with an increase in the knowledge of climate-resilient legumes among smallholder farmers classified as having medium knowledge. This means that employment status often influences agricultural knowledge. The positive relation between nutritional value and knowledge of smallholder farmers means that smallholder farmers have medium knowledge about the nutritional benefits of tepary beans and this influenced their adaptation to climate-resilient legumes. Farmers with no knowledge of nutritional value of tepary beans are unlikely to adopt. There is a positive relationship between land size and knowledge of smallholder famers on climate-resilient beans, meaning smallholder farmers with no knowledge are more likely to be exposed to, and eventually acquire, knowledge about climate-resilient crops.

The negative relationship between production cost and knowledge of climate-resilient legumes mean that high input costs can reduce the smallholder farmers' willingness to invest in gaining new knowledge, especially under medium knowledge levels where the farmers are aware but may lack confidence or resources for full adoption. For smallholder farmers with no knowledge, high production costs represent a significant limitation, as they may not be able to invest in the early steps of understanding and experimenting with new crops such as tepary beans

Binary Logistic Regression model was used to generate the results of the socio-economic factors influencing smallholder farmers' perceptions on climate-resilient legumes such as tepary bean in selected villages of Limpopo Province, South Africa. The model has a total of six significant variables. Thus, production cost, land size and marital status were positively significant, while nutritional value, employment and access to extension services were negatively significant. Production cost of tepary beans has a positive impact on how smallholder farmers perceive climate-resilient legumes, especially the tepary bean. This suggests that smallholder farmers are willing to accept higher costs if they perceive the long-term benefits of the crop in terms of climate resilience. The is a positive relationship between land size and smallholder farmers' perceptions towards climate resilient beans and it means that larger sizes of land influence farmers to easily adopt to new and different crops. Marital status and perceptions of smallholder farmers on climate-resilient beans have a positive relationship which suggests that married smallholder farmers have people who depend on them and may be more open to adopting climate-resilient crops to maintain food security and income stability, making them likely to perceive the benefits of such crops positively.

The significant negative relationship between the nutritional value of tepary beans and the perceptions of smallholder farmers means that nutritional value of tepary beans is not enough to balance concerns about its adaptability to climate stresses, particularly in areas where climate-resilient traits are prioritized over nutritional content. Results also show that the negative relationship between employment status and perceptions means that smallholder farmers with alternate employment are unlikely to invest in or perceive the benefits of climate-resilient beans, especially if their income is not only through farming. The significant negative relationship between access to extension services and smallholder farmers perceptions. This means that available extension programs might not be tailored to the needs of smallholder farmers who are growing climate-resilient legumes.

6.3 CONCLUSION

A summary of the key conclusions drawn from the data in Chapters 4 and 5 is also provided in this section to draw conclusions on the hypotheses of the study. The study had two hypotheses' statements. The first one was that there is no difference in the level of knowledge and perceptions of smallholder farmers on climate-resilient legumes in the study area, and the second one was that the socio-economic factors do not influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in the selected areas of Limpopo Province.

As per results in Chapter 4 and 5, it has been shown that socio-economic factors, which are the employment status, production cost, nutritional value of tepary beans, land size, marital status and access to extension services have either a negative or positive relationship which affects the knowledge and perceptions of smallholder farmers on climate-resilient legume crops. This proves that the socio-economic factors influence the smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in the study area. The impact of the nutritional value of tepary beans on knowledge levels suggests that awareness campaigns highlighting the nutritional benefits of these legumes may influence how farmers perceive them. Smallholder farmers with greater awareness of these benefits are expected to have higher knowledge levels.

The significance of production costs influences how smallholder farmers perceive tepary beans. Those who view the production as costly are unlikely to have much knowledge and will perceive tepary beans negatively. For smallholder farmers with no knowledge, high production costs may limit them, and they might choose other legume crops that they believe are lower to produce over tepary beans. Production cost of tepary beans positively influence how smallholder farmers perceive climate-resilient legumes, especially the tepary bean. Employment status of the smallholder farmer suggests that households with employed smallholder farmers may have greater resources or access to information, contributing to higher knowledge levels. Results also show that the negative relationship between employment status and perceptions means that smallholder farmers who have other jobs besides farming are unlikely perceive the benefits of climate-resilient beans as they have other sources of income.

Land size results showed that smallholder farmers with bigger land are likely to adopt to climate-resilient tepary beans because more land does not limit farmers. Marital status influences the perceptions of smallholder farmers on climate-resilient beans as married smallholder farmers are always looking for ways to maintain food making them more likely to perceive such crops positively. The significant negative relationship between access to extension services and smallholder farmers perceptions might be due to available extension programs not being for the specific needs of smallholder farmers who are growing legumes.

The hypothesis that there is no difference in the level of knowledge and perceptions of smallholder farmers on climate-resilient legumes in the study area was rejected. The findings indicate significant differences in the level of knowledge and perceptions among farmers, suggesting variability in their awareness and attitudes toward climate-resilient legumes such as tepary beans. These differences could stem from factors such as exposure to agricultural training, access to information, or varying farming experiences.

The hypothesis that socio-economic factors do not influence smallholder farmers' knowledge and perceptions on climate-resilient legumes was also rejected. The results show that socio-economic factors like employment status, production costs, nutritional value, land size, marital status, and access to agricultural extension services, substantially impact the farmers' knowledge and perceptions. This indicates that these factors play an important role in shaping how smallholder farmers understand and perceive climate-resilient legumes.

6.4 RECOMENDATIONS

This section includes suggestions that were derived from the study's findings. The study's reasoning claimed that the data collected could potentially help stakeholders and policymakers who are concerned about preserving and enhancing food security in the midst of the changing climate by enabling them to conduct focused and well-informed responses. In addition to adding to the existing body of knowledge on the topic, this study will give policymakers, academics, and practitioners important insights and raise awareness for additional research on the role tepary beans play in promoting food security and adaptation to climate change.

These are the recommendation of the study:

1. The study proposes that Department of Agriculture and Land Reform fast-track Land Reform policies and strategies to provide farmers with secured tenure rights. This because policy measures that increase smallholder farmers' access to and security of land can improve their capacity to grow climate-resilient crops. Thus, secure tenure and land reforms may provide smallholders the courage to fund long-term adaption plans.
2. Policymakers could create training programmes that accommodate various land size classifications. Smaller landowners may get customized guidance that emphasizes increasing yields and lowering costs, while larger landowners could receive more advanced instruction on climate-resilient crops.
3. Policymakers should look for measures to subsidise the cost of producing climate-resilient crops, like providing smallholder farmers with financial assistance. Despite the greater initial production costs, smallholder farmers would be likely to adopt such crops if the costs of production were lowered.

4. Promoting household-based farming models, in which both partners take part in decision-making, may increase the uptake of climate-resilient crops. These initiatives can improve family labour dynamics in order to encourage the adoption of climate-resilient farming methods.
5. Given that perceptions are greatly influenced by land size, extension services could target smallholders with small land sizes by offering them specialized assistance in implementing climate-resilient crop practices. Farmers with smaller land sizes may have more positive perceptions of adoption programs that lower adoption risks.
6. Extension services should be made for the specific needs and challenges of smallholder farmers, particularly regarding climate-resilient crops. Programs should prioritize practical, context-specific advice on growing climate-resilient beans, including information on management practices and market opportunities. In addition to extension services, smallholder farmers need access to complementary support services, like credit, market access, and inputs, to facilitate adopting climate-resilient crops. Extension services should be integrated with these complementary services to enhance the overall adoption process.

Since the smallholder farmers are the ones facing the challenges listed in Table 4.6 within Chapter 4 directly, they listed ways in which they could be encouraged and assisted to participate more in farming. These are some of the solutions they mentioned:

1. Provision of water through tanks and/or boreholes since majority farms on dryland.
2. Resources to assist on improving the quality and quantity of their produce.
3. Recent information about climatic conditions and types of crops suitable for each climate. This information should be free or affordable (through workshops) as most do not have access to the internet and are unemployed.
4. Smallholder farmers in the sampled villages felt neglected by the Department of Agriculture and wish to get more visit.

These recommendations could assist smallholder farmers in the study area and other areas to be knowledgeable about climate-resilient crops and change their perceptions for the better.

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APPENDIX

Appendix 1: Ethics clearance certificate

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3935, Fax: (015) 268 2306, Email: tukiso.sewapa@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **09 April 2024**

PROJECT NUMBER: **TREC/60/2024: PG**

PROJECT:

Title:	Investigating smallholder farmers' knowledge and perceptions on climate resilient Legumes in selected villages of Limpopo Province, South Africa: a case of tepary bean
Researcher:	PC Mokheseng
Supervisor:	Prof MP Senyolo
Co-Supervisor/S:	Dr LS Gidi
School:	Agriculture and Environmental Sciences
Degree:	Master of Agricultural Management (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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Appendix 2: Departnment if Agriculture and Rural Development approval letter

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
AGRICULTURE AND RURAL DEVELOPMENT

Ref: 12R
Enquiries: Dr T. Raphulu

05 July 2024

P.C. Mokheseng [redacted]
University of Limpopo

RE: APPLICATION TO CARRY OUT RESEARCH UNDER THE DEPARTMENT OF AGRICULTURE & RURAL DEVELOPMENT: CAPRICORN SOUTH

1. Kindly take note that your request to conduct research titled "INVESTIGATING SMALLHOLDER FARMERS' KNOWLEDGE AND PERCEPTIONS ON CLIMATE-RESILIENT LEGUMES IN SELECTED VILLAGES OF LIMPOPO PROVINCE, SOUTH AFRICA: A CASE OF TEPARY BEAN" has been granted.
2. You are required to contact the office of the Deputy Director: Capricorn South to brief them on the study, to request up-to-date database of small-holder legume farmers and assistance.
3. Kindly take note that you will be expected to hand over a copy of your final report to the Department for record purposes. You may also be invited to share your findings in the Departmental Research Forum.
4. Hoping that you will find this in order.

Kind regards

Dr. T. Raphulu
Chairperson: Research Committee

05/07/2024
Date

67/69 Biccard Street, POLOKWANE, 0700, Private Bag X9487, Polokwane, 0700
Tel: (015) 294 3135 Fax: (015) 294 4512 Website: http://www.lda.gov.za

The heartland of Southern Africa - development is about people!

Appendix 3: Consent form

CONSENT FORM

Tittle of research project: **INVESTIGATING SMALLHOLDER FARMERS' KNOWLEDGE AND PERCEPTIONS ON CLIMATE-RESILIENT LEGUMES IN SELECTED VILLAGES OF LIMPOPO PROVINCE, SOUTH AFRICA: A CASE OF TEPARY BEAN.**

Dear Participant

This study aims to analyse factors that influence smallholder farmers' knowledge and perceptions on climate-resilient legumes such as tepary beans in selected villages of Limpopo Province, South Africa.

Please note that your participation in this study is highly voluntary. You have the right to participate in this study, and you also have the right to pull out at any time without any penalty. Your identity and all the details you share will be confidential and be used for the purpose of this study only and will not be disclosed to anyone. The study can only provide the information to stakeholders and policymakers concerned with improving food security in the midst of a changing climate.

For further questions you can contact me, Miss Mokheseng P.C: (076 836 0263/ mokhesengpalesa17@gmail.com), my academic supervisor: Professor Senyolo P.M (015 268 4628/Mmapatla.senyolo@ul.ac.za) and my co-supervisor Dr Gidi L (073 965 8088 /lungile.gidi@ul.ac.za),

CONSENT

I have read the above information related to the research and data gathering and I would like to participate in the study.

Signature of participant: ……………………………Date: …………………………

Appendix 4: Questionnaire

QUESTIONNAIRE

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

1. Gender of the household head

Male	Female
1	0

2. Age of the household head ___________
3. Household size ______________
4. Land size in hectares _________________
5. Experience in crop farming ________________
6. Educational level of household head

No formal education	Primary education	Secondary education	Tertiary education
1	2	3	4

7. Employment status of the household head.

Yes	No
1	0

8. Marital status

Single	Married	Widow/er	Divorced
1	2	3	4

9. Access to extension services

Yes	No
1	0

SECTION B: SMALLHOLDER FARMERS' KNOWLEDGE

Statement	5.Strongly agree	4. Agree	3. Not sure	2. Disagree	1.Strongly disagree
I know tepary beans					
I know legume crops that can tolerate drought, high temperatures, or that can grow when rainfall is not enough.					
I know any tepary beans characteristics and benefits					
The unavailability of resources limits the type of crops grown.					
I think tepary beans can help maintain food security in the households.					
I think tepary beans can help limit the effects of climate change such as droughts, erratic rainfall, and high temperatures.					
I have received information related to legumes in the last six months.					
I have received information related to climate change in the last six months.					

SECTION C: SMALLHOLDER FARMER'S PPERCEPTIONS

Statement	5. Strongly agree	4. Agree	3. Not sure	2. Disagree	1. Strongly disagree
Climate-resilient crops help save money that we use to purchase food.					
Climate-resilient crops help in reducing food insecurity.					
The department of agriculture offers the needed support to smallholder farmers.					
I have received information related to legumes in the last six months.					
I have received information related to climate change in the last six months.					
I am satisfied with the quality of the crops I am producing.					
I am satisfied with the quantity of the crops I am producing.					
I have knowledge of climate-resilient crops.					
Producing my own crops is better than buying them.					
I would advise other smallholder farmers to grow climate-resilient crops.					
I prefer tepary beans over other beans.					

SECTION D: KNOWLEDGE ABOUT TYPOLOGIES OF DIFFERENT LEGUME CROPS

1. Which legume crop do you know?

Tepary beans	Soybean	Groundnut	Cowpea	Other
1	2	3	4	5

2. List the legume(s) that you are growing.

....

....

....

....

3. Indicate which characteristics apply to each legume crop.

	Soybean	Groundnut	Cowpea	Tepary bean	Other
1-Drought and heat tolerant.					
2-Requires a lot of water for growth.					
3- Affected mostly by pests and diseases					
High nutritional value					
Long shelf-life					
Low-cost production					

4. Is there any additional information you would like to share with me regarding to any other legume crops.

……
……………………………………………………………………………

……
……
………………………………………………………………….

5. List at least three main challenges you face in smallholder farming.

………

………

………

……..

6. List at least three ways in which you can be encouraged or supported to help engage more in smallholder farming.

………

………

………

……..

7. Is there anything else that you would like to bring to my attention before we conclude with our discussion?

………

………

………

……..

I would like to thank you for dedicating your time to participate in my survey. Your participation is highly appreciated and will assist in my research.