# Redesigning Production Systems for Water-Use Efficiency Amongst Smallholder Farmers at Numbi, South Africa

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# DEDICATION.

To God almighty, the Morepje and Gininda family in their entirety for the unwavering support and encouragement throughout the span of the project.

**DECLARATION.**

Mr Morepje M.T (Student) solely wrote the dissertation under the guidance of Dr Agholor A.I (Supervisor). The work was not distributed to other institutions and organizations for any qualification, awards, or publication in journals except through the authorization of the University of Mpumalanga. In conclusion, the work of other authors has been used and acknowledged.

Dr Agholor AI. 2024.

Mr Morepje MT. 2024.

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- Dr Agholor, A.I., for his part in supervising the project.
- The community of Numbi for participating in the project.

**ABSTRACT.**

The study sought to redesign production systems for water-use efficiency (WUE) using a quantitative approach to enhance food security and rural livelihoods. The study focused on water management practices, and challenges hindering the transition towards water efficient smallholder production systems. The study was guided by the following objectives: i) to examine production systems employed by smallholder farmers for WUE, ii) to assess the challenges in accepting formal water management systems iii) to determine the application of water-use efficiency approaches by smallholder farmers in the Numbi area, and iv) to determine the acceptance of formal water management systems at the study area. A structured questionnaire was administered to 141 farmers in the Numbi area of Mbombela Local Municipality, Mpumalanga province, South Africa. The analysis of the study's goals and objectives was carried out using various analytical tools including descriptive statistics, one-way ANOVA, and the binary logistic regression model. The study findings reveal that farmers understand the WUE concept as they have adapted WUE approaches which align with their primary irrigation water sources and farming practices. The smallholder farmers have also demonstrated a cautious utilisation of the limited water resource. However, the rate at which these production systems adapt to the changing climate is reduced by resource constraints. These challenges encompass insufficient irrigation equipment, inadequate knowledge and skills in irrigation water management, the impact of climate change, limited access to financial institutions for funding, and modest returns from seasonal sales. Therefore, the study recommends that to redesign production systems for water-use efficiency (WUE), several factors such as socioeconomic considerations, collaborative efforts among farmers, long-term planning, awareness building and training, technology and infrastructure integration, climate-resilient farming practices, financial support mechanisms, as well as robust research and extension services have to be prioritised by stakeholders and policy makers.

**Keywords:** Technology adoption, water-use efficiency, smallholder farming, irrigation water management, climate change.

## LIST OF ACRONYMS.

AgriSETA – Agricultural Sector Education and Training Authority.

ANOVA - Analysis of Variance.

ARC – Agricultural Research Council of South Africa.

CSA – Climate-Smart Agriculture.

NGO - Non-governmental organisation.

OFA - Off-Farm Activities.

PDP – Professional Development Project.

SAPs – Sustainable Agricultural Practices

SPSS – Statistical Package for the Social Science.

StatsSA – Statistics South Africa (Government institution responsible for statistics).

TAM – Technology Acceptance Model.

ToC – Theory of Change.

WUE – Water-use efficiency.

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# 1. CHAPTER ONE: INTRODUCTION.

## 1.1. Overview.

Improved food security and livelihoods have been linked to increased water-use efficiency. Additionally, it results in the conservation of water, enabling water-use for other purposes such as ecological sustainability (Anantha *et al.,* 2021). Accordingly, using water more effectively is important for preserving the scarce natural resource and the environment (Jayasiri *et al.,* 2022). The term "Water-Use Efficiency (WUE)" describes the amount of liquid that is used for plant metabolic processes to liquid they lose from transpiration. Finding effective water-use approaches to crops with low water requirements, avoiding water wastage, and maintaining optimum agricultural environments for crop production are the key tactics to improve water-use efficiency (Zahoor *et al.,* 2019). Since most impoverished communities globally are in poorly rain-fed regions, increasing sustainable land and water-use within these regions would have several advantages (Asmamaw, 2017).

Globally, rain-fed agriculture is common to smallholder farmers, meaning much of the water source for irrigation emanates from seasonal rainfall (Espinosa-Tasón *et al.,* 2022). With rain-fed farming, farmers may only cultivate their crops during one planting season annually owing to rainwater reliance, steering towards an augmented risk of recurrent flooding and drought (Jaramillo *et al.,* 2020). As per Jaramillo *et al.* (2020), the poor efficiency of rain-reliant farming systems is the primary contributory factor to food and livelihood insecurity. Furthermore, owing to the country's dwindling mean annual precipitation and the unequal delivery of surface and groundwater due to climatic and geographical circumstances, South Africa is a water-scarce developing nation (Thakur *et al.,* 2020).

Smallholder farmers are different from commercial farmers in the sense that they only have limited capital including land and water and they are heavily reliant on a handful of cash crops and family as labour (Duker *et al.,* 2020). Some of the primary traits of smallholder farmers' farming systems are that they are non-complicated, use old technology, have low productivity, and are dominated by women (Aguilar *et al.,* 2018). Furthermore, the farming industry is under increasing stress to expand the efficacy of water utilized for agricultural purposes as the battle for scarce water resources on the globe intensifies owing to population and wealth expansion (Karimidastenaei *et al.,* 2018). Temperature fluctuations, precipitation, and the reoccurrence of severe climatic events significantly influence crop output, including smallholder farmers' household livelihoods, food security, and their state of well-being (Shahzad *et al.,* 2021).

### 1.2. Problem statement.

South Africa's rainfall patterns vary depending on regions, with some areas of the country receiving a lot of rain and others receiving little rainfall but in short bursts, making it difficult to rely heavily on rainfall for agricultural production (Rankoana, 2020). Additionally, the timing of the rainfall is unpredictable which can negatively impact crop yield (Chikosi *et al.,* 2019). As a result, the nation's agricultural sector relies heavily on irrigation in addition to rainfed agriculture as irrigation helps to stabilise crop yields and provide farmers with more control over their water supply (Meza *et al.,* 2021).

Different from commercial farmers, smallholder farmers are unable to irrigate their production systems regularly due to costs associated with irrigation, limited access to water, poor irrigation infrastructure, and environmental factors resulting from climate change (Mkuhlani *et al.,* 2020). Thus, rainfed farming holds greater appeal for farmers with limited resources, given its lower cost compared to irrigated agriculture as this accessibility makes it a viable option for smallholder farmers who have restricted financial capacities (Prasanna *et al.,* 2021). Thus, leading smallholder farmers in rural communities are left with no option but to use rainfed agricultural systems (Sigalla *et al.,* 2022). Rainfed agricultural systems are susceptible to a host of environmental hazards such as drought affecting crops, livestock, and irrigation practices mainly in regions characterised by low rainfall and limited moisture (Meza *et al*, 2021).

In the context of smallholder farming communities in Numbi, South Africa, the adoption of water-efficient production systems presents a critical challenge that is influenced by multifaceted socio-economic factors. Despite advancements in plant and water science aimed at enhancing water use efficiency in agriculture, the translation of technical knowledge into practice among smallholder farmers remains limited. This gap between technical solutions and on-the-ground realities underscores the need for a comprehensive understanding of the socio-economic dynamics that shape farmers' decision-making processes.

Smallholder farmers in Numbi face numerous socio-economic constraints that hinder their ability to adopt water-efficient production systems. These constraints include but are not limited to limited access to financial resources, inadequate institutional support, knowledge gaps, cultural beliefs, and socio-economic disparities within the community. Furthermore, the complex interactions between these factors exacerbate the challenges faced by farmers and contribute to the persistence of inefficient water use practices.

While traditional approaches to addressing water use efficiency have primarily focused on technical interventions rooted in plant and water science, such approaches often overlook the socio-economic realities of smallholder farming communities. Neglecting socio-economic factors not only undermines the effectiveness of interventions but also perpetuates the marginalization of smallholder farmers who lack the resources and support necessary to adopt sustainable agricultural practices.

Against this backdrop, the study aimed to redesign smallholder production systems for water-use efficiency (WUE) by investigating socioeconomic challenges and constraints in redesigning production systems for WUE. For the study aim to be achieved, the study looked at the application of WUE approaches at the study area and evaluated the socioeconomic factors faced by farmers with the acceptance of formal water management systems by smallholder farmers.

#### 1.2.1. Study purpose.

The study was conducted with the intention of redesigning smallholder production systems for water-use efficiency (WUE) by examining the current water usage patterns and challenges faced by smallholder farmers, including factors such as limited access to water, non-efficient irrigation methods, and environmental pressures. Moreover, the study sought to develop effective strategies, and management practices tailored to address the specific demands of smallholder farmers, ensuring that water is used optimally in their production systems. Thus, the study showcased the benefits of adopting water-efficient practices through empirical data, demonstrating increased crop yields, reduced water wastage, and improved financial outcomes.

In South Africa, smallholder farming is at risk from unsustainable farming methods, as emphasised by Popoola *et al.,* (2018). Other studies have emphasised the implementation of water-efficient farming strategies among smallholder farmers (Matchaya *et al.*, 2019; Nhamo *et al.,* 2020). The enhancement of water-use efficiency in agriculture has gained heightened importance in tackling the issue of achieving adequate food production while reducing water usage, especially in areas confronted by water scarcity. These advancements encompass a range of strategies that aim to optimize crop yield, reduce water waste, and mitigate environmental impacts.

A major development has been the acceptance of precision irrigation approaches, such as drip irrigation and micro-irrigation as these methods deliver water straight to the plant's root zones, cutting down on water loss caused by evaporation and runoff (Kumar *et al.,* 2023). By improving the accuracy of water distribution, these methods contribute to increased efficiency in water utilisation and enhanced crop yields. The integration of smart irrigation technologies has also revolutionized water management in agriculture using real-time data from sensors and weather forecasts as farmers' ability to make well-informed decisions regarding the timing and quantity of irrigation is intensified (Zia *et al.,* 2021). This data-driven approach ensures that water is applied only when needed, preventing both under- and over-irrigation and optimizing water utilization.

Advancements in soil moisture monitoring have further refined water-use efficiency as soil moisture sensors give precise, real-time details about the moisture levels in the soil (Cooper *et al.,* 2021). Thus, this data guides farmers in tailoring their irrigation practices to suit the specific water needs of crops, thereby reducing waste and improving overall efficiency. Strategic crop selection and breeding efforts have yielded drought-resistant crop varieties that demand less water while maintaining respectable yields (Begna, 2022). Hence, developing crops that can thrive with limited water availability, farmers can make more sustainable use of their water resources. The concept of precision agriculture, which employs technologies such as GPS, drones, and satellite imagery, has gained prominence (Bwambale *et al.,* 2022). These technologies allow farmers to identify variability in water needs across their fields and apply irrigation and other agricultural growth initiatives precisely where required. This approach reduces resource wastage while ensuring optimal crop growth.

Traditional practices of cover cropping, and mulching have also made a resurgence as these methods minimise soil moisture loss through evaporation and inhibit weed growth, thereby reducing the overall water requirements of main crops (El–Metwally *et al.,* 2022). In regions grappling with water scarcity, innovative dry farming approaches have emerged that involve cultivating crops without additional irrigation, relying on soil moisture retention and careful selection of drought-tolerant crops (Mekonen *et al.,* 2022). While challenging, this technique showcases the potential to drastically curtail water usage in agriculture.

With all these advancements, there is insufficient research on the willingness and feasibility of smallholder farmers in poor communities to embrace droughts resistant crops, rainwater harvesting, precision agriculture and soil moisture monitoring. Thus, this study aspired to examine water-efficient approaches, socioeconomic factors, and smallholder farmers' willingness to accept formal water management systems with the intention of redesigning production systems for water-use efficiency. To this end, the study focused on various factors, including the available water sources, affordability of the proposed techniques, the effectiveness of the existing production system in use, and the perspectives of small-scale farmers regarding the adoption of novel approaches.

The outcomes of this study will aid governmental bodies and other stakeholders invested in smallholder farming in informing their planning and research efforts concerning water-use efficiency, as there is limited data available on redesigning production systems for water-use efficiency precisely customised to fit the requirements of smallholder farmers. Moreover, empowering smallholder farmers with the information and expertise required to implement water-efficient practices will ensure the sustainability of these methods beyond the study. In its essence, the study sought to narrow the divide concerning water scarcity and agricultural productivity, benefiting both smallholder farmers and the environment while contributing to broader goals of sustainability and resilience.

### 1.2.2. The objectives of the study.

#### 1.2.2.1. The general objective.

The wide-ranging objective of the study is to redesign smallholder production systems by improving the methods and practices used in smallholder agricultural production to optimise water usage.

#### 1.2.2.2. The specific objectives.

The study was directed by the subsequent set of objectives:

i. to examine production systems utilised by smallholder farmers for water-use efficiency.
ii. to assess the challenges in redesigning production systems for increased agricultural production.
iii. to determine the application of water-use efficiency approaches by smallholder farmers at Numbi.
iv. to determine the acceptance of formal water management systems in the Numbi area.

#### 1.2.2.3. Research questions.

The study endeavoured to provide answers to the following questions:

i. What are the production systems employed by smallholder farmers?
ii. Are there challenges encountered in redesigning production systems by smallholder farmers at the study area?
iii. What are the water efficiency approaches used by smallholder farmers?
iv. Do smallholder farmers accept formal water management systems?

## 1.3. Study limitations.

Smallholder farmers' perspectives were the only ones considered in the study not those of their commercial counterparts as a large portion of irrigation is tailored for commercial purposes. Livestock farmers, extension agents, private and governmental organisation in charge of providing extension services do not form part of the survey owing to time constraints, budget, and logistical requirements to reach all smallholder farming stakeholders within the study area. Thus, the study findings are biased towards mixed farmers and those cultivating crops. Due to the use of the simple random sampling method, sampling and selection bias could have unintentionally occurred while conducting the survey. The data analysis tools such as the five-point Likert scale are prone to social desirability bias and response bias.

### 1.4. Originality of the study.

While there is existing research on water-use efficiency and agricultural practices, this study's originality lies in its in-depth exploration of various innovative strategies. The study combines technological advancements of drip irrigation and precision farming with traditional methods such as rainwater harvesting and integrated agroforestry systems. By considering a diverse range of solutions, the study offers a comprehensive solution for smallholder farmers to choose from, catering to different contexts and preferences. The study further recognizes that successful solutions cannot be solely technological. The uniqueness of this study resides in its comprehensive exploration of socio-economic factors, encompassing an assessment of how the suggested strategies influence the livelihoods of smallholder farmers. By assessing factors such as economic viability, adoption barriers, and the potential for income generation, the study goes beyond technical feasibility to evaluate the practicality and sustainability of proposed interventions.

The inclusion of case studies within the study adds another layer of originality. By analysing successful water management models and learning from previous adoption failures in similar contexts, the study offers practical insights into the real-world challenges and opportunities that farmers face. This approach provides a grounded understanding of the complexities involved in implementing water-efficient practices. The study's originality also stems from its interdisciplinary nature. It combines agriculture, environmental science, economics, and sociology. This approach acknowledges that addressing water scarcity and enhancing water-use efficiency requires collaboration across different fields to create comprehensive and effective solutions.

Rather than proposing generic recommendations, the study aims to provide tailored guidance for different stakeholders. It offers actionable recommendations for policymakers, extension services, financial institutions, and other relevant actors. This specificity enhances the study's originality by ensuring its findings can be practically applied within diverse contexts. By focusing on smallholder farmers, the study addresses a vulnerable and often marginalized group. The originality lies in its emphasis on not just short-term water efficiency but also long-term agricultural system resilience. This aligns with sustainable development goals and reflects the study's commitment to creating lasting positive impacts.

To conclude, the originality of this study lies in its combination of technological innovation, socio-economic integration, real-world case studies, tailored recommendations, and a focus on long-term resilience. By approaching the issue of water scarcity in agriculture with such a multifaceted perspective, the study contributes valuable insights that have the potential to drive meaningful change in smallholder farming practices, water management, and overall agricultural sustainability.

### 1.5. Definition of terms.

- **Water-use efficiency.**

According to Malik *et al.,* (2021), water-use efficiency (WUE) pertains to the ratio of effectively utilized water within a purely hydrological context.

- **Smallholder farmers.**

Farmers solely focused on the cultivation of few cash and sustenance crops on smaller farmland, lacking adequate resources and capital as characterised using family labour (Gc and Hall, 2020).

- **Production systems.**

Briefly explained, agricultural production systems are the methods a farmer employs to suit his or her needs for food, fuel, and fibre (Ahmed *et al.*, 2022).

- **Climate-smart agriculture.**

A strategy that directs measures to change farming systems into environmentally friendly and climate-resilient ones (Mukherjee, 2022).

## 1.6. The structure of the dissertation.

The study is structured across eight chapters, presented in the following sequence: introduction, South African agriculture, literature review, theoretical and conceptual framework, methodology, results and discussion, empirical results of the study, and summary, conclusion, and policy implication. The chapters are as follows:

- Chapter 1: Introduction.
- Chapter 2: South African agriculture.
- Chapter 3: Literature review.
- Chapter 4: Theoretical and conceptual framework.
- Chapter 5: Methodology.
- Chapter 6: Results and discussion.
- Chapter 7: The empirical results of the study.
- Chapter 8: Summary, conclusion, and policy implication.

# 2. CHAPTER TWO: SOUTH AFRICAN AGRICULTURE.

## 2.1. The context of the agricultural industry in South Africa.

The farming industry and institutions administering and managing the industry have seen tremendous transformation in the century since 1910 (Bennett and Van Sittert, 2019). In addition to making a significant contribution towards the nation's overall economic prosperity a century ago, agriculture was essential in helping the nation overcome its issues with rural poverty (Emmanuel and Babalola, 2022). This had been made possible by significant and ongoing governmental aid in the form of subsidies for the establishment of rural infrastructure, extensive farmer development programs, training and educational initiatives, and a determined push for the automation of agricultural output (Khojely *et al.*, 2018). Since 1994, there has been a renewed expectation that the agricultural industry would provide jobs, with a focus on income redistribution (Lipper and Zilberman, 2018). Although there are obvious and strong pressures to do so, the methods used appear to be harming the sector's overall growth and productivity performance (Zantsi *et al.*, 2022). If the past is any indication of the future, the type and rate of productivity growth will ultimately decide the potential of the nation's farming industry to generate jobs and revenue in a fast-shifting multinational agroecosystem (Bennett and Van Sittert, 2019).

Consolidating various aspects of government on farming and agricultural training into a unified Department of Agriculture had been previously the primary emphasis of the government; this endeavour lasted close to three decades to accomplish (Zantsi, 2021); and featured funding initiatives to boost employee skills through research and extension services. Contrary to the periods which came after, legislative management, administrative functions, and research and dissemination of agricultural expertise have all been handled within the sole ministry throughout that era (Mtshali and Akinola, 2021). Severe rates of poverty, reoccurring droughts, and ongoing economic recession were notable characteristics of the agricultural sector throughout this time (Lipper and Zilberman, 2018). Following the country's democratisation as well as the implementation of land restructuring and farmer reparations programmes to redress historical wrongdoings, a significant emphasis by government was on development by offering monetary and specialised assistance to new and established farmers (Emmanuel and Babalola, 2022) The concern of identifying suitable support networks and support distribution channels for the South African farming industry has re-emerged in recent years (Khojely *et al.*, 2018). The Union of South Africa was founded in the early 1900s, and throughout the century ever since, the farming industry of the nation and the institutions in charge of and supporting it has seen major changes (Zantsi *et al.*, 2022). In addition to making a significant contribution to the nation's economic overall prosperity a century ago, farming was essential in helping the nation overcome its issues with abject poverty (Khojely *et al.*, 2018). It was accomplished with the help of significant and ongoing governmental assistance in the form of funding for the creation of rural infrastructure, extensive farmer development programs, educational and training initiatives, and a determined push for the modernization of agricultural output (Bennett and Van Sittert, 2019). Since 1994, there has been a renewed expectation that the agricultural industry would provide jobs, with a focus on wealth apportionment. Although there are obvious and strong incentives to do so, the methods used appear to be harming the sector's net productivity and expansion efficiency (Chamberlain and Manseau, 2019). If the past should be an indication of the future, the kind, as well as the rate of productivity increase, will eventually decide the potential of South African agribusiness to provide jobs and revenue in a fast-shifting multinational agroecosystem (Strauss *et al.*, 2021).

## 2.2. Agricultural practices within the context of the South African farming industry.

The range of agricultural practices within the South African agricultural sector is broad, influenced by the nation's diverse climate, geography, and various agricultural domains. South Africa produces a variety of crops on a commercial scale, including maize, wheat, sugarcane, citrus fruits, and grapes amongst others (Bonetti *et al.*, 2022). Modern practices involve precision agriculture techniques, irrigation systems, and advanced seed varieties to maximize yields and quality (Barasa *et al.*, 2021). Also, livestock farming is practised which includes cattle, sheep, goats, poultry, and pigs with pastoral systems being common, and that use both traditional and commercial approaches (Mthembu *et al.*, 2019). Additionally, intensive livestock production methods are also used, often incorporating modern breeding, and feeding practices (Vaintrub *et al.*, 2021).

The wine industry holds substantial economic imp ortance for the country and is involved in the practice of viticulture (Andreoni *et al.*, 2021). Vineyards are found in diverse regions, including the Western Cape. Trellising and canopy management approaches are used to optimize grape quality (Panzeri *et al.*, 2020). Moreover, the varied climate facilitates the growth of a wide array of fruits, vegetables, and nuts. Crop rotation, integrated pest management, and greenhouse cultivation are also used to ensure optimal yields and product quality (Salami *et al.*, 2022). To address soil degradation and erosion concerns, the adoption of conservation agriculture practices such as minimum tillage, mulching, and crop rotation have been on the rise. These practices are aimed at improving soil health and minimising environmental impact (Van Antwerpen *et al.*, 2021).

Organic farming practices are gaining popularity as consumers demand more sustainably produced food (Malek *et al.*, 2019). Organic farms avoid synthetic pesticides and fertilizers, focusing on natural methods to manage pests and enhance soil fertility (Pasupulla *et al.*, 2021). Nevertheless, many rural communities continue to practice traditional farming methods that are adapted to their local environments (Kom *et al.*, 2020). These include indigenous knowledge of planting, harvesting, and using native plants. In coastal areas, aquaculture is practiced which includes rearing fish, shellfish, and aquatic plants (Trottet *et al.*, 2022).

Consequently, this aquaculture industry contributes to both domestic consumption and export (Chitiga-Mabugu *et al.,* 2021).

### 2.2.1. South African agricultural irrigation systems and its role on food security.

The design of South African agricultural irrigation systems is diverse, incorporating techniques such as drip, sprinkler, and pivot systems, tailored to different crops and regions (Du Toit, 2018). These systems are crucial for optimizing water usage, enhancing crop yields, and mitigating water scarcity challenges (FAO, 2016). By employing efficient irrigation methods, farmers can ensure the sustainable use of water resources while maintaining agricultural productivity.

The role of irrigation systems in promoting food security in South Africa cannot be overstated. Despite variable climatic conditions, these systems enable farmers to produce crops consistently (FAO, 2020). Reliable water supply provided by irrigation systems supports the cultivation of a wider range of crops, thereby increasing agricultural productivity (Stats SA, 2019). This enhanced productivity contributes to food availability and stability in supply, ultimately bolstering food security for the population.

Furthermore, irrigation systems play a vital role in diversifying agricultural production in South Africa. They allow for the cultivation of crops that are not naturally suited to the country's climate, thereby expanding the range of available food options (Du Toit, 2018). This diversification strengthens the resilience of the agricultural sector, reducing dependence on a few staple crops and enhancing overall food security.

In conclusion, the design and implementation of irrigation systems in South Africa are integral to ensuring food security. These systems optimize water usage, support consistent crop production, diversify agricultural output, and ultimately contribute to a more resilient and secure food supply chain for the nation (FAO, 2020; Stats SA, 2019). Continued investment and innovation in irrigation infrastructure are essential to sustainably meet the food needs of the growing population.

**2.3. The economic impact of South African agriculture.**

Agriculture contributes to South Africa's Gross Domestic Product (GDP) by providing value-added products and creating employment opportunities (Chitonge, 2021). While its share of GDP has declined over the years due to the growth of other sectors, agriculture remains an essential contributor to the country's GDP (Bhorat *et al.*., 2020). Additionally, the agricultural sector offers employment to a significant segment of the nation's population, particularly in rural regions (Sutherland, 2020). It supports livelihoods for smallholder farmers, farm laborers, and agribusiness workers across various segments of the value chain (Liu *et al.*, 2023). Within South Africa, agriculture assumes a central role in advancing rural development and alleviating poverty. It provides income opportunities for communities living in rural and remote areas, contributing to their economic well-being (Osabohien *et al.*, 2019). To add, the agricultural sector is critical for ensuring food security by producing a significant portion of the country's food supply (Zwane, 2019). It helps stabilize food prices and reduces dependence on imported goods.

Agriculture stimulates the growth of the agribusiness sector, including input suppliers, equipment manufacturers, and service providers (Rob, and Cattaneo, 2021). This broader ecosystem generates economic activity beyond primary production. Moreover, agriculture, especially wine and horticultural industries, contributes to South Africa's tourism sector (Booyen, 2020). Agri-tourism allows visitors to experience farming activities and local produce, generating additional revenue for communities (Back *et al.*, 2020). Investments in agricultural research and innovation have led to the development of improved crop varieties, sustainable farming practices, and technological advancements (Jayne, and Sanchez, 2021). This contributes to productivity gains and economic growth. Hence, the agricultural sector attracts both domestic and foreign investment, particularly in areas such as agribusiness, processing, and export-oriented production (Sutherland, 2020). Thus, this enhances long-term economic sustainability. Agriculture provides raw materials for various industries, including textiles, pharmaceuticals, and biofuels (Ramchuran *et al.*, 2023). These industries benefit from a stable and diverse supply of agricultural inputs.

#### 2.3.1. Job opportunities within the South African sector.

The significance of the South African agricultural sector goes beyond its influence on economic growth and export earnings. It also stands as a vital provider of employment for a diverse range of individuals, ranging from rural households engaged in smallholder farming to skilled experts within the commercial farming sphere. According to the most recent data from the Statista (2023) in figure 1, the agricultural sector employed around 868 000 people in 2021.

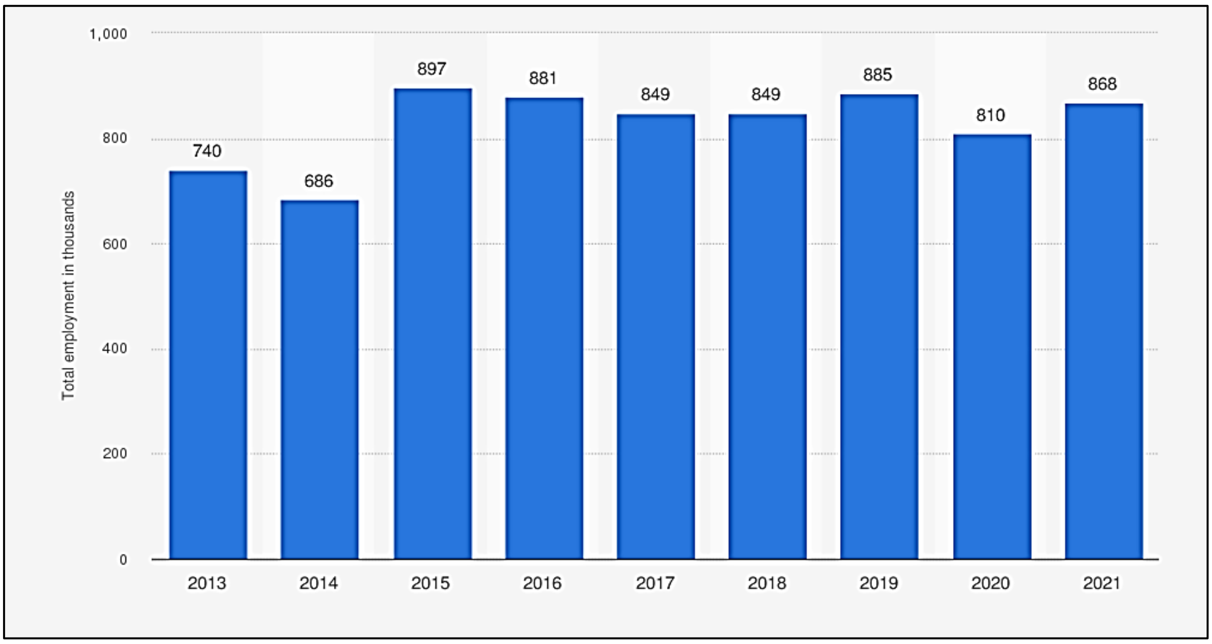



Figure 1: Agriculture, hunting, fisheries, and forestry labour in 1000s.
Source: Statista, 2023.

This workforce is distributed across various agricultural activities encompassing farming, livestock rearing, horticulture, agribusiness, and related services as highlighted in figure 2 (AgriSETA, 2021).

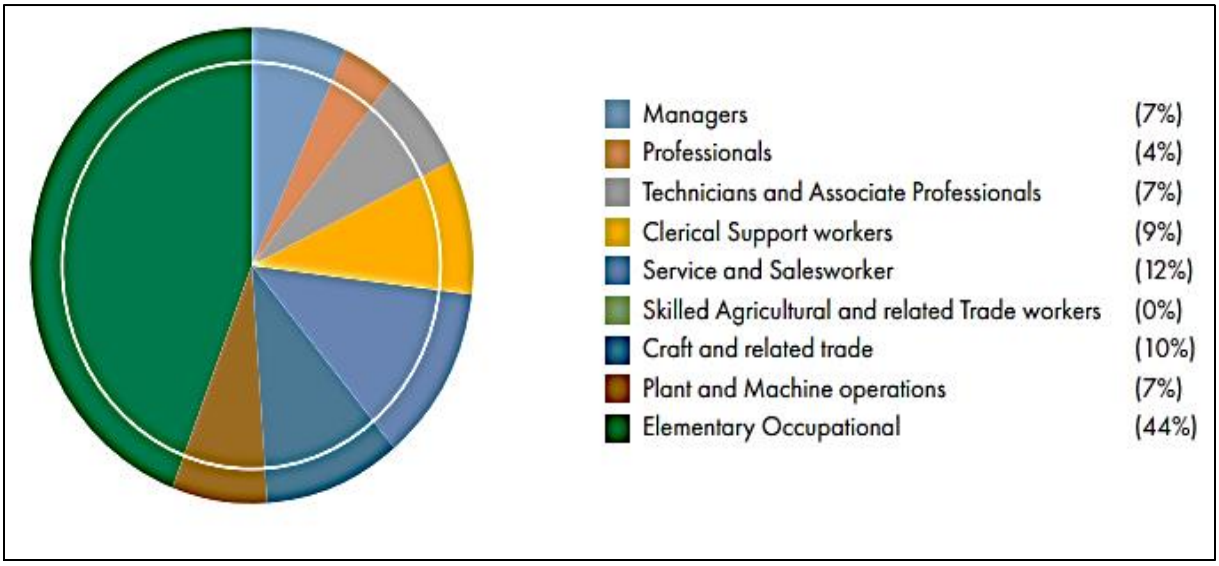



Figure 2:Agricultural employment breakdown by occupation.
Source: AgriSETA, 2021.

The sector's labour force is characterized by its diversity as highlighted by AgriSETA shown in figure 2, comprising not only farmers and laborers directly engaged in production but also professionals involved in research, technology, marketing, and other supporting roles. Furthermore, the agricultural sector plays a notable role in South Africa's economy, accounting for about 2% of the country's GDP in 2021 (Statista, 2023a), as depicted in figure 3.

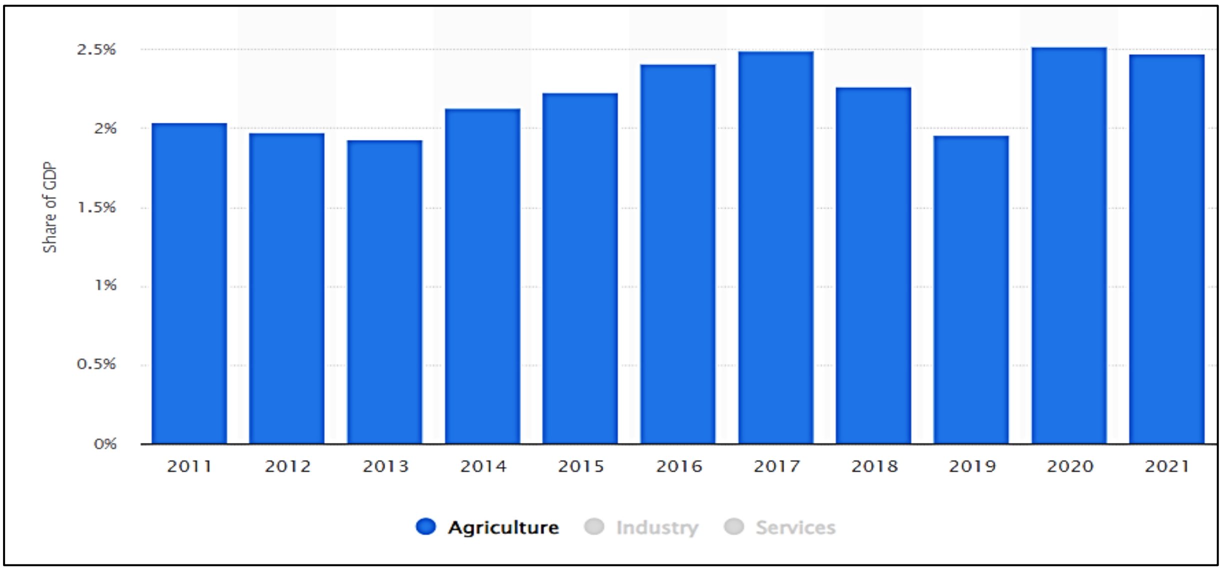



Figure 3: Agricultural sector GDP contribution from 2011-2021.
Source: Statista, 2023a.

In conclusion, the agricultural sector's dual role as a substantial employer and economic contributor showcases its integral position within South Africa's socio-economic fabric. Its impact is not only felt through employment opportunities and GDP contribution, but also resonates throughout various aspects of the nation's development, making it a cornerstone of the country's prosperity and growth.

### 2.3.2. Provincial contribution towards agricultural employment.

During the initial quarter of 2023, approximately 888,000 individuals have been employed within the primary agriculture sector, marking a 3% increase compared to the previous quarter and a 5% rise from the same period last year (Statista, 2023). This growth is notably higher than the established baseline agricultural employment figure of 780,000 (De Necker, 2023). The employment surge was propelled by the Western Cape, KwaZulu-Natal, and Gauteng regions as seen in figure 4 below during the first quarter of 2022 (Statista, 2023).

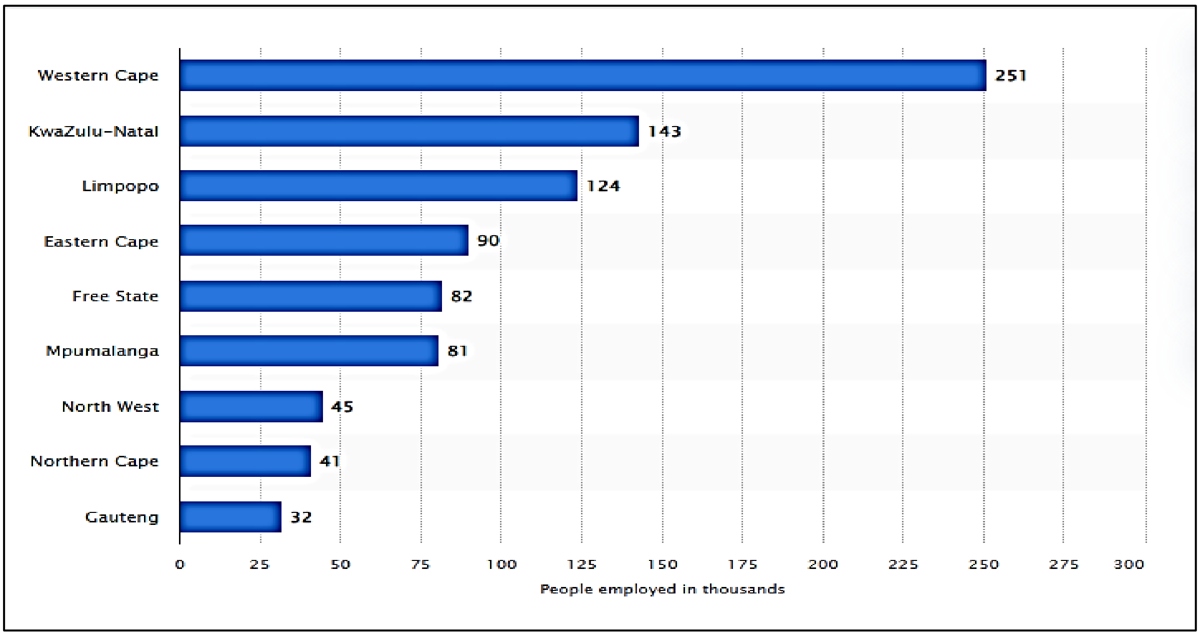



Figure 4: Employment breakdown per province in thousands.
Source: Statista, 2023.

The South African provinces of Western Cape and KwaZulu-Natal lead in agricultural employment for a variety of reasons; these provinces are known for their diverse agricultural activities. The Western Cape is known for wine production, fruit cultivation, and agriculture-related tourism (Van Zyl, and Du Plessis, 2022). KwaZulu-Natal has a mix of subtropical and temperate climates, supporting an extensive variety of crops such as sugarcane, citrus, and subtropical fruits (Flynn, 2023). The climates in these provinces are suitable for a wide range of crops and agricultural practices. Favourable climate conditions enable year-round production and diversified crop portfolios, leading to increased employment opportunities (Parehwa, 2020).

These provinces often have better access to markets, both domestic and international with the Western Cape and KwaZulu-Natal having access to ports and export opportunities, enhancing their market reach (Tatsvarei *et al.*, 2021; Goedhals-Gerber, and Khumalo, 2020). The Western Cape benefits from a strong agro-tourism industry due to its wine routes and picturesque landscapes and this combination of agriculture and tourism generates additional employment opportunities in various sectors, such as hospitality, restaurants, and food services (Van Zyl, 2019).

### 2.4. South African trading partners and exports.

South Africa serves as a significant exporter of agricultural commodities including fruits, vegetables, wine, citrus, and processed foods. The European Union, the United Kingdom, and nearby African countries represent significant export destinations, as outlined in figure 5 below. As a member of the African Continental Free Trade Area (AfCFTA), South Africa aims to strengthen trade ties within the African continent (Mhonyera, and Meyer, 2023; The World Bank, 2020). Thus, the agreement promotes intra-African trade and economic integration. Furthermore, the country has established trade relations with countries around the world as these relationships help diversify export markets.

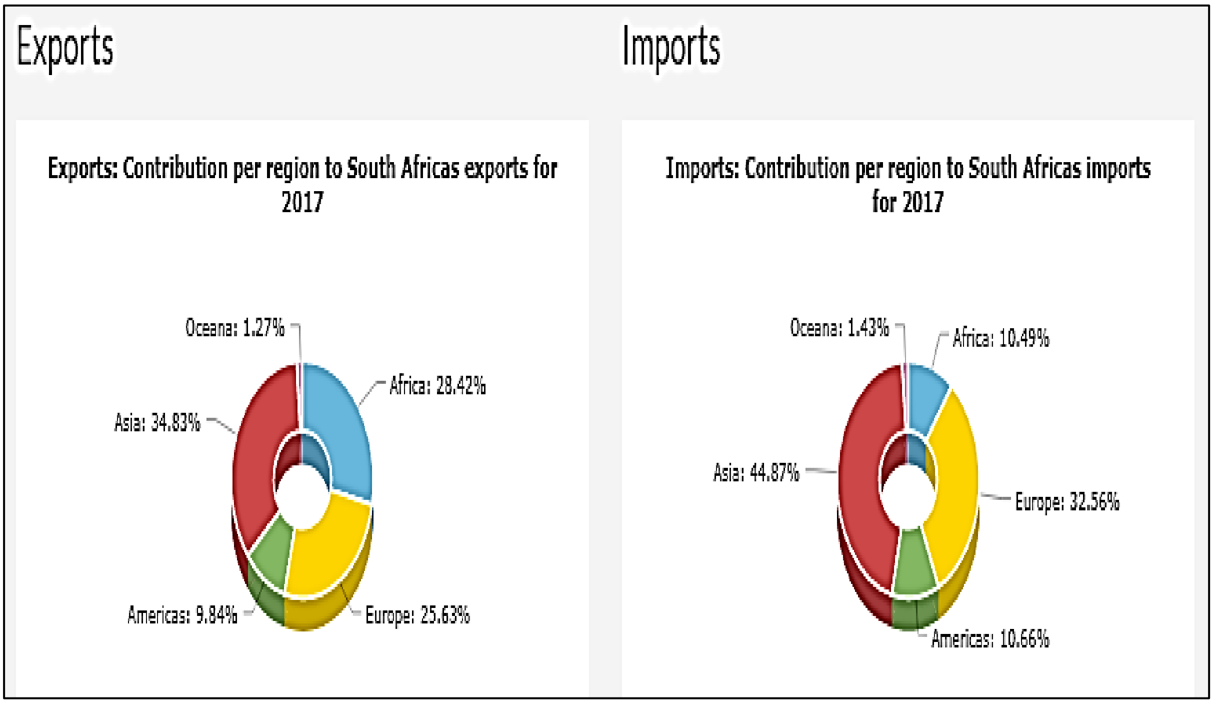



Figure 5: South Africa's 2017 exports and imports globally.
Source: South African Market Insights, 2018.

The country exports wine to various markets, with the European Union, the United States, and the United Kingdom being important consumers (Lubinga *et al.*, 2021). Additionally, South Africa is a major citrus exporter, supplying products like oranges, lemons, and grapefruits to markets worldwide, including Europe, Asia, and North America (Ryan, 2022). Processed agricultural products, including canned fruits, fruit juices, and processed meat products, are also part of the country's export portfolio (Shafi *et al.*, 2022). However, South Africa imports certain agricultural goods such as rice, wheat, and palm oil to meet domestic demand (d'Amour, and Anderson, 2020).

While the country benefits from trade agreements, it also faces challenges such as tariffs, non-tariff barriers, and sanitary and phytosanitary regulations in some markets (Hattingh *et al.*, 2020). Thus, to reduce dependence on a few key markets, South Africa continues to explore new trade partners and products. This diversification helps mitigate risks associated with fluctuations in demand and external factors (Joshua *et al.*, 2020). Hence, meeting international quality and safety standards is crucial for maintaining and expanding trade relationships as compliance with standards ensures that South African products are competitive in global markets. Despite the agricultural export strength, the country faces challenges such as infrastructure limitations, logistic inefficiencies, and sometimes volatile exchange rates (Mandeya, and Ho, 2021). However, its diverse agricultural sector presents opportunities for growth and increased trade partnerships.

### 2.4.1. South African trade with African nations.

The African continent remains a prominent market, constituting 37% of South Africa's agricultural exports in 2022 (The Agricultural Business Chamber, 2023). These exports are particularly concentrated within the Southern African Development Community (SADC) region. Figure 6 below highlights the types of agricultural goods exported to other African nations and South Africa's imports from other African countries in 2019.

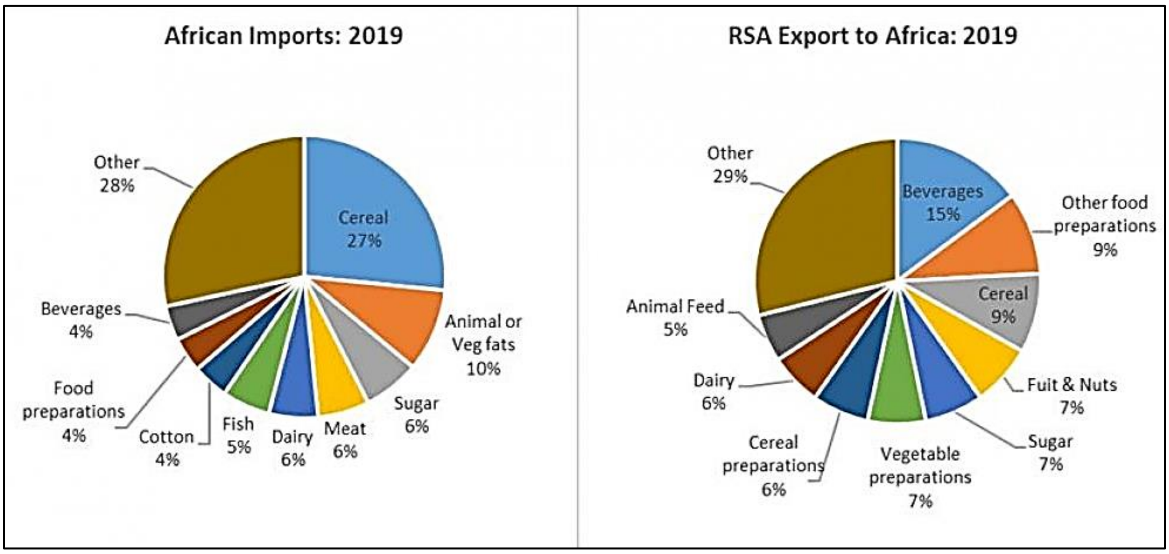



Figure 6: South African imports and exports with African countries.
Source: Polity, 2021.

Nevertheless, South Africa's potential for agricultural exports within the African continent is curtailed by structural obstacles. These impediments hinder the agricultural sector's capacity to extend its exports into untapped markets.

### 2.4.2. South African trade with the European Union.

Over the period from 2016 to 2021, South Africa's exports to the EU exhibited an annualized growth rate of approximately 11.7%. The substantial increase in South African exports to the EU from 2020 to 2021 is responsible for most of this expansion, as exports surged at an annual rate of 30.1% during this timeframe (European Union, 2021). In comparison, South Africa's total global exports experienced an annualized growth rate of 10.2% between 2016 and 2021, according to the European Union (2021), as shown in figure 7.

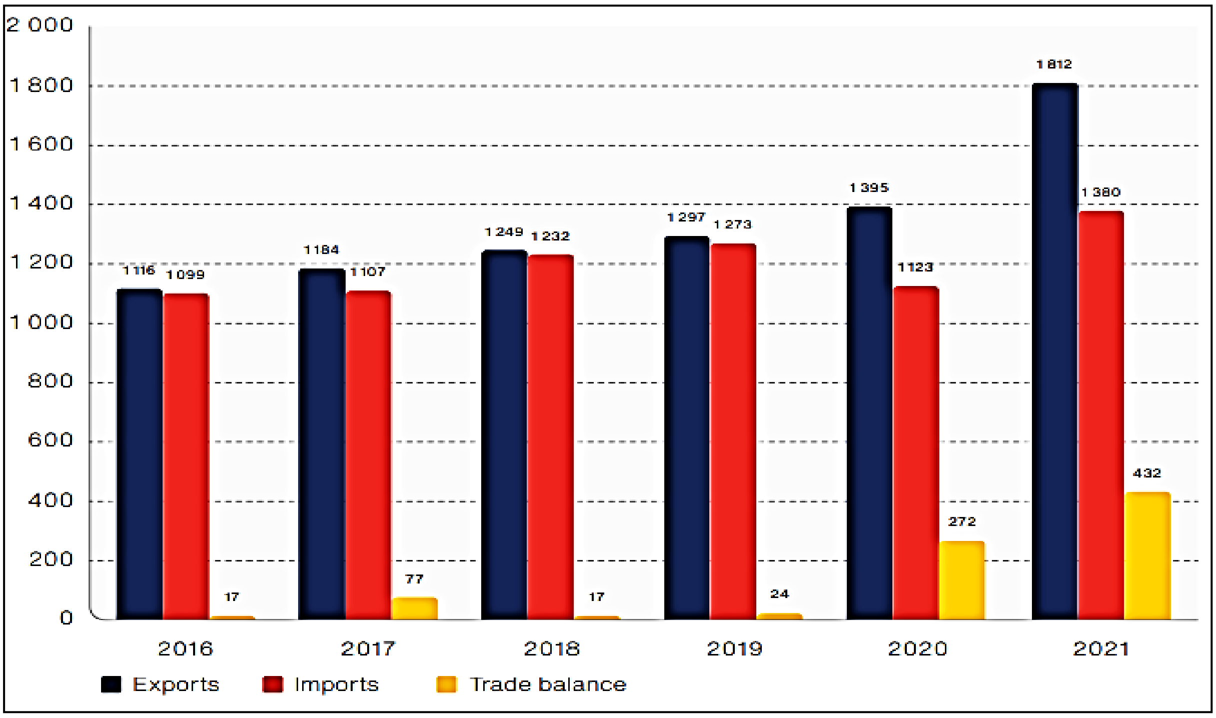
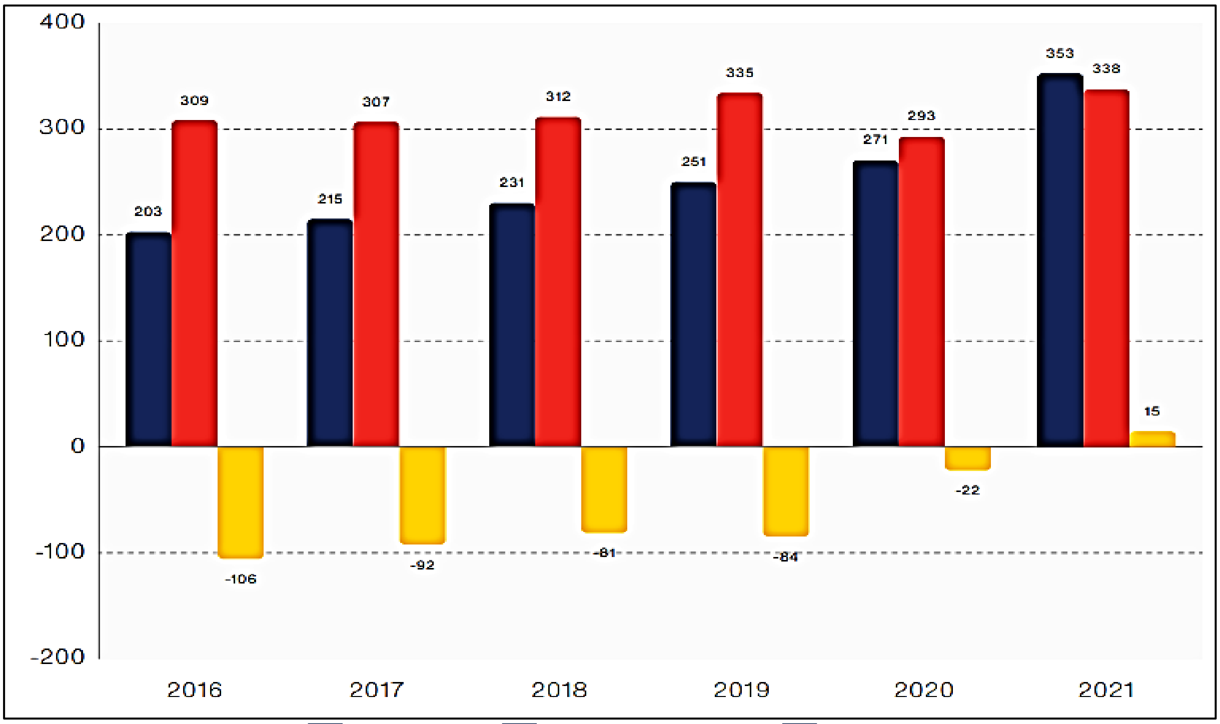



Figure 7: South African trade with the world in ZAR billions.
Source: European Union, 2021.

Between 2016 and 2021, imports from the EU grew at an annualised rate of 1.8%. The significant improvement in domestic economic activity contributed to a surge in imports from the EU of 15.2% between 2020 and 2021. This increase in imports has however been overshadowed by South Africa’s remarkable export performance, resulting in a reversal of the country’s net trade position with the European Union as shown in figure 8.




**Legend: Exports Imports Trade balance**

Figure 8: South African trade with European nations in ZAR billions.
Source: European Union, 2021.

In 2021 South Africa recorded a positive trade balance with the EU for the first time since the implementation of the Trade and Development Cooperation Agreement (TDCA) with the EU in 2004, reflecting an overall improvement of R37 billion in the year 2020.

## 2.5. Challenges of the South African industry.

The South African agricultural sector faces a range of challenges that impact its development and sustainability. Several of these encompass the impacts of climate change, which include irregular rainfall patterns, extended periods of drought, and rising temperatures. These alterations pose risks to crop yields, livestock well-being, and the overall productivity of agriculture (Rankoana, 2020). Water scarcity exacerbates these challenges, affecting irrigation and water-dependent farming. To add, Insufficient infrastructure, especially in rural areas, hampers efficient transportation and distribution of agricultural products whereas limited access to modern technology, such as advanced farming equipment and digital tools, can hinder productivity and competitiveness (Khoza *et al.*, 2019).

While South Africa is a major agricultural exporter, barriers such as trade restrictions, tariffs, and sanitary and phytosanitary regulations can limit market access for its products. Navigating international trade agreements can be challenging for the sector (Hlungwani, 2023). Rural poverty is a concern in many farming communities, impacting access to education, healthcare, and economic opportunities (Smidt, and Jokonya, 2022). Moreover, food security remains a challenge, with some segments of the population struggling to access nutritious and affordable food (Raidimi, and Kabiti, 2019). Also, unsustainable agricultural practices, such as overgrazing and improper land management are problematic as they can lead to soil erosion and degradation (Kgaphola *et al.,* 2023). Therefore, ensuring the well-being of soil health becomes paramount for securing agricultural sustainability in the long run. Lastly, the upward trend in energy costs, spanning electricity and fuel, has the capacity to raise production expenses for farmers (Akinbami *et al.,* 2021). Ensuring reliable and affordable energy access is crucial for the sector's competitiveness.

### 2.6. Conclusion.

South African agriculture embodies diverse promise and complexity, ranging from traditional to modern practices driven by technology. Historically pivotal for rural employment and livelihoods, shifts in mechanisation, land ownership, and global market demands have reshaped the dynamics of farm employment. Agricultural exports and imports are vital for the economy, contributing to foreign exchange earnings and domestic food security. South Africa's varied produce, from fruits and wines to grains and meats, solidifies its role in global food trade. Nevertheless, challenges persist, including water scarcity, shifting weather patterns, and climate change impacts, jeopardising productivity.

# 3. CHAPTER THREE: LITERATURE REVIEW.

## 3.1. Background of water-use efficiency in agriculture.

Over ten thousand years ago, according to Zair *et al.,* (2021), in the cradle of civilization in western Asia, farming systems began to develop in the Eastern Mediterranean. As a result of being the origin of numerous important grain and legume crops as well as the early domestication of livestock, the region has historically contributed significantly to global agriculture (Balkrishna *et al.,* 2021). The evolution and features of the present agrarian structure have been discussed greater in part, along with the agricultural improvement from some of these primitive periods through the Roman era, the interim years of Arab as well as Turkish rule, and the increasingly notable colonial era of the 19th and 20th centuries (Angelakis *et al.*, 2020). Farmers have faced the same issue throughout this period of evolution: cultivating crops in a climate characterized by extremely unpredictable and frequently chronically insufficient rainfall (Bhaga *et al.,* 2020). It may seem strange that scientists and researchers lately are rediscovering enhanced crop rotational systems as well as fallow practices like those used by the Romans over two thousand years ago (Teira Brión, 2022). Several of the techniques established to mitigate the unpredictability of rainfall have been developed using the common elements of existing agricultural production systems (Adugna, 2021).

### 3.1.1. Water-use efficiency (WUE) and its application.

Where water is the primary issue limiting crop development, it has been discovered that any improvement in water-use efficiency attained by lowering or reducing non-productive usage of water could cause an increase in transpiration and yield (Gorthi *et al.,* 2019). Malik *et al.,* (2021) refers to water-use efficiency (WUE) as the proportion of the sum of water used effectively from a strictly hydrological perspective. Since the hydrological notion of water-use efficiency reflects a portion, that cannot be greater than one or smaller than zero, it complies with the mandatory requirements for a just description of efficiency (Sordo-Ward *et al.,* 2019).

By enhancing the effectiveness of water distribution and implementation systems, in addition to improving the scheduling and dispersion of irrigation, water-use efficacy in irrigated farming can be improved (Koech and Langat, 2018). The option WUE provides for choosing the ideal cultivation strategy for areas with limited water resources is what makes the transpiration ratio element of water-use efficiency of agricultural importance (Zahoor *et al.*, 2019). The rainfall distribution through its hydrological context has been the climatological element influencing water-use efficiency (Li *et al.*, 2020). It has been noted that factors influencing how effectively water is used, as defined hydrologically, depend on the chemical while also considering the physical traits of the soil (Wu *et al.*, 2022).

### 3.2. Sustainable agricultural production systems.

Existing agricultural systems differ rapidly in response to changes in production costs, customer demands, and growing risks about the safety, security, and effects climate change has on the environment where food is produced (Gomez-Zavaglia *et al.*, 2020). The necessity to create commercially viable production systems for farmers while also addressing society's concerns about environmental effects and nutritional value is important (Giller *et al.*, 2021). "An initiative to making food and fibre that is lucrative utilizes on-farm assets efficiently intending to minimise risks associated with farming towards the ecosystem and individuals, conserves the natural performance and efficiency of the land and water, and supports vibrant rural communities" defines sustainable agricultural production (Sarkar *et al.*, 2020a). According to the same understanding of the term, the five overarching objectives of sustainable production systems are to meet people's needs, enhance the natural environment and preserve it, boost natural resource use efficiency, enhance the profitability of agribusiness, and raise the standard of living for both producers and society (Xie *et al.*, 2019). The sustainability goals can be achieved through the employ of integrated agricultural production (Sekaran *et al.*, 2021).

To promote environmentally friendly agricultural practices, Sekaran *et al*. (2021) define integrated farming systems as production systems that combine various farming techniques and make use of natural resources by combining plant-based and animal-based resources. The intrinsic ability of integrated agricultural production to distribute and so lessen farmer risks through the diversification of companies, enabling farmers to utilize a wider range of marketing channels, is one of its key advantages (Leterme *et al.,* 2019). Although integrated agriculture can significantly reduce overall risk, managing the many trade-offs of each distinct farming component is a significant problem in addressing all the issues listed (Miedaner and Juroszek, 2021).

### 3.2.1. Sustainable agricultural practices in South Africa.

Crop yield among smallholder farms in South Africa, remains low irrespective of the land quality, despite previous efforts by agricultural scientists, extension services, and governmental institutions (Myeni *et al.,* 2019). The protracted droughts, lengthier dry spells, scarce water and unavailable fertilizer, poor farmlands, and ineffective agrarian techniques cause low harvests (Mwangu, 2021). The sustainability of rainfed food production is threatened by the expected rise in the probability of undesired climatic conditions such as droughts and high temperatures exacerbated by climate change (Klutse *et al., 2021*). Dependence on rain-fed farming including the inability to adapt, the bulk of South African smallholders' way of living and access to nutrition is inclined to be affected by the changing climate (Tantoh *et al.*, 2022).

By the year 2035, South Africa's population is projected to be 80 million as per Goldblatt cited by Myeni *et al.,* (2019). Considering a shifting climate and a swiftly expanding population, the methods employed for food production must be ecologically viable to ensure nourishment and fulfil societal requirements (Sarkar *et al.,* 2020a). This is a viable approach in growing farm output from the currently available farmland while minimizing harmful environmental effects (Newton *et al.,* 2021). It does this by optimizing external inputs and making efficient utilisation of the natural assets that are already available (Newton *et al.*, 2021). As a result, the recommendation has been made to employ Sustainable Agricultural Practices (SAPs) to enhance the efficiency, productivity, and sustainability of smallholder production systems while also safeguarding the environment (Myeni *et al.,* 2019). Smallholder farmers should be encouraged to embrace and apply these practices for the impact of SAPs to be understood (Adnan *et al.,* 2018). Numerous research group institutes, NGOs, and other stakeholders have sought to implement, and recommend these SAPs throughout various regions on the African continent (Abegunde *et al.,* 2019). The adoption rate amongst smallholder farmers is nevertheless relatively low in South Africa considering the well-researched yield gains linked to SAPs (Ntshangase *et al.*, 2018).

### 3.3. Farmer socioeconomic factors influencing the acceptance of formal water management systems and agricultural innovation.

Smallholder farmers' willingness to adopt new agricultural innovations is significantly influenced by the specific characteristics of the innovation, including its compatibility with the diverse environmental conditions it is designed for (Dhraief *et al.*, 2018). The decision-making process often involves the consideration of creative techniques suggested for diffusion, and these decisions are typically the outcome of evaluating the benefits of the new technology in relation to adoption costs (Worku, 2019). Whether one is a producer, distributor of such technology, or a smallholder farmer, a comprehensive understanding of the factors influencing these decisions is of paramount importance (Pathak *et al.,* 2019; Silverberg, 1991). An economic assessment of the adoption of improved agrarian practices is essential for elucidating attitudes toward technology adoption. This assessment considers various factors, including an individual's assets and personal characteristics, the presence of inaccurate information, levels of uncertainty, institutional constraints, and the availability of necessary inputs and infrastructure (Gatheri, 2021).

### 3.3.1. Farmer's perception of the technology and associated benefits.

The nature of innovation serves as a prerequisite that sparks farmers' interest in adopting new proposed technologies. The chance to experiment with the technology on a smaller level significantly influences farmers' willingness to embrace the suggested innovation (Dissanayake *et al.,* 2022). AESON (2012) drew from Mignouna *et al.,* (2011) to explore factors influencing farmers' decisions to adopt improved maize technology in Kenya. They found that the distinctive features of the technology greatly affect farmers' decision-making. Farmers initially evaluate whether the new technology aligns with their current needs, environment, and future goals before deciding on its adoption (Mignouna et al., 2011). According to Jha *et al.,* (2019), farmers also assess the effectiveness of the suggested technique before embracing it. Adesina and Zinnah (1993) investigated the adoption of modern rice varieties and found that farmers' perceptions regarding the attributes of the new rice variety play a pivotal role in shaping their readiness to adopt it (AESON, 2012). In a similar vein, Wandji *et al.,* (2012) arrived at a comparable conclusion to that of Adesina and Zinnah (1993) in their exploration of farmers' attitudes toward innovative aquatic farming practices in Cameroon, building upon the research by Obiero *et al.,* (2019). Favourable farmer perceptions regarding fish farming technology were shown to drive its heightened adoption. Consequently, Wandji et al. (2012) underscored the significance of engaging farmers in the evaluation process of novel technology to ensure its alignment with their requirements.

### 3.3.2. Land availability and size in influencing the acceptance of water management systems.

The available land for farming significantly influences the adoption of new innovative practices (Weyori *et al.,* 2018). The dimensions of available arable land yield both advantageous and disadvantageous consequences for adoption, and certain determinants of adoption can also exert a negative influence on farm size. Consequently, technologies dependent on size can only be adopted on larger farms, in contrast to smaller ones (Sanusi *et al.*, 2021). Larger farm sizes offer an advantage as farmers can allocate portions of their land to test innovative practices, unlike those with smaller plots. Mechanized technology and animal traction also rely on farm size to turn production into profit, as noted by Feder *et al.,* (1985) cited by Hu *et al.,* (2019).

The adoption of modern farming technologies is adversely affected by farm size, however in cases of resource-intensive or land-saving innovations, smaller farmlands may incentivise the embracing of technology (Barnes *et al.,* 2019a). Limited land may lead farmers to opt for land-saving techniques over increased output, such as environmentally sound technologies and zero grazing (Udimal *et al.,* 2017). In contrast, there are insignificant or moderate relationships between adoption and farm size in some cases. For instance, integrated pest management implementation remains unaffected by farm size, indicating that farmers of any size can use this approach (Rejesus, 2019). Similarly, large land holdings do not significantly impact the likelihood of adopting farmer field schools for integrated crop management (Mariyono, 2018).

The studies mentioned consider the entire farm size, not just the cropland where technological innovation is implemented. Comparing farm size with proposed innovations helps estimate the extent of technology adoption, as overall farm size influences adoption levels (Li et al., 2020). Calculating suitable land area for new technology offers insights into how technology adoption affects farm size (Barnes *et al.,* 2019b).

### 3.3.3. The financial implications of adopting new technology.

The assessment of costs and benefits linked to adopting a suggested innovation plays a pivotal role in aiding farmers to ascertain whether the new technology carries any unfavourable financial consequences (Acevedo *et al.,* 2020). They assert that the cost of adopting innovative practices can negatively impact the acceptance of such practices. This is illustrated by the example of the World Bank's 1990s initiative in the Sub-Saharan African region, which removed subsidies on fertilizers and seeds, leading to elevated costs for these inputs (Muzari *et al.,* 2013).

Numerous studies have demonstrated that higher adoption costs deter farmers' interest in adopting new technology. Makokha *et al.,* (2001) as cited by Diro *et al.,* (2022) corroborate Muzari *et al.,* (2013) through their investigation of factors influencing fertilizer and manure acceptance in Kenya's Kiambu county. They found that expensive labour, input costs, and a lack of packaging materials hindered fertilizer adoption. Similarly, Ouma *et al.,* (2002), in an inquiry in Embu County, Kenya, about fertilizer and hybrid seed adoption, identified high labour costs as a constraint to adoption (Yokamo, 2020). Yokamo (2020) also referred to an inquiry by Wekesa *et al.,* (2003) regarding the acceptance of an innovative maize cultivar. This study found that expensive seeds and their unavailability discourage farmers from adopting such technology.

### 3.3.4. Off-farming livelihoods effects on the acceptance of formal water management systems.

The acceptance of proposed innovative agricultural practices or equipment can benefit from off-farm revenue, as indicated by Dhraief et al. (2018). In many emerging economies, households use off-farm revenue to overcome credit limitations (Ankrah Twumasi *et al.,* 2021). In areas with restricted financial support, income from non-farming activities can substitute for credit (Danso-Abbeam *et al.,* 2019). Diiro (2013) suggests that non-farm activities can help farmers afford new inputs to enhance production (Yenewa and Demis, 2021).

The study of Diiro (2013) on the impact of farm income on the effectiveness of introducing modified maize cultivars in Uganda demonstrated that households with supplementary income from non-farm activities displayed reduced likelihood of adopting intensive purchased inputs. However, their expenditures were notably higher compared to those without off-farm income

(Twinamatsiko *et al.*, 2020). However, not all technology categories exhibit a positive connection between income sourced from non-farm activities and adoption. Studies focusing on labour-intensive innovative practices indicate an opposing correlation, suggesting a negative relationship between off-farm income and adoption (Mugumaarhahama *et al.,* 2021). Hence, the endeavour to secure income from non-agricultural sources by farmers could possibly impede the adoption of suggested innovative practices. This is because it diminishes the pool of domestic labour accessible for agricultural tasks.

### 3.3.5. Farmer's social circle on the acceptance of formal water management systems.

Participating in a social unit where ideas, information, and trust are exchanged enhances a farmer's social capital (Ganguly *et al.,* 2019). Being part of such a unit influences a farmer's capacity to learn about and benefit from new technology through interactions with those who have already adopted it (Cofré-Bravo *et al.,* 2019). Zhang *et al.,* (2020) refer to Uaiene and Arndt (2009), Highlighting the vital role that social networks play in shaping a farmer's decision-making process, particularly in adopting agricultural technology. Farmers often share information within their social circles, facilitating mutual learning.

Examining the impact of community-based organisations on the adoption of improved banana cultivars in Uganda, Katungi and Akankwasa's study (2010) revealed that farmers involved in such groups demonstrated a higher propensity to embrace innovative tools and practices. These organizations facilitated discussions about proposed innovations, thus contributing to the increased acceptance of these practices (Akongo and Chonde, 2020). However, Birir (2021) highlighted the negative aspect of belonging to a social group-free riding behaviour. Foster and Rosenzweig (1995) as cited by Dissanayake *et al.*, (2022) examined the uptake of sustainable agricultural techniques in India and found that social networks' educational impact improved the profitability of adoption. However, they also observed instances where farmers seemed to exploit their neighbours' costly experimentation with modern technology (Caeiro, 2022).

According to Bandiera and Rasul (2002), learning externalities have both positive and negative consequences. Participating in the technological exploration by other farmers may be advantageous in exposing new technologies and could provide an incentive to benefit from such experimentation.

### 3.3.6. Access to information on available water management innovations.

Having access to data on the proposed innovative technology influences the adoption of technology (Kumar *et al.,* 2018). Farmers are then able to be knowledgeable on the availability of innovative practices or machinery including its efficacy and consequently increase the probability of farmers adopting the appropriate technology (Smidt and Jokonya 2022). Hence, Smidt and Jokonya (2022) state that it is only when farmers have been made aware of the technology will the technology adoption process commence. Uncertainty pertaining to the efficacy of new practices or innovation reduces as more information about the technology is made available to the farmers. Thus, each farmers negative perceptions of the technology significantly reduces over time (Dhraief *et al.,* 2018). Having access to data on the proposed innovative practices or equipment may also have a negative outcome in that farmers are discouraged from using technology as their perceptions may be different from researchers who introduce such technologies (Uaiene and Arndt, 2009; Lowenberg-DeBoer and Erickson, 2019). Simtowe and Mausch (2018) also reiterate a similar view that farmers may not accept the new technology due to having inappropriate information about the new technology.

Lack of exposure to information and its availability, within the community of farmers increases the reluctance of farmers to implement innovation and new technologies. As more technological information becomes available that is not seen by farmers, the knowledge gap increases resulting in the non-adoption of new technologies (Shita *et al.*, 2018). Therefore, dependable, and precise information concerning innovative practices or machinery helps reduce the negative effects farmers might associate with the proposed innovative technological practices (Shita *et al.,* 2018). The existence, benefits, and user instruction of proposed innovative practices or equipment are important for farmers to adopt the technology (Kumar *et al.,* 2018).

### 3.3.7. The influence of farmer support on water management systems.

Being able to acquire extension services is a pivotal element in the drive for increased technology adoption (Kumar *et al.,* 2018). Extension practitioners often have the task of ensuring that smallholder farmers are aware of the presence, benefits, and instructions for the effective use of the innovation or equipment (Chao, 2019). Moreover, the primary duty of agricultural extension practitioners is to link the farmers and users of agricultural innovative technology with the developers or researchers of that innovative technology (Liu *et al.*, 2021). Therefore, the cost associated with the transfer of innovative technology from the manufacturer of the technology to bigger and more diverse groups of farmers is lowered (Chao, 2019). The approach extension practitioners use when selecting a farming community leader, is to select an influential farmer who can persuade other farmers into adopting technology (Takahashi *et al.,* 2020). A symbiotic relationship within agrarian extension services and farmer uptake of new technology has been noted by Caffaro *et al.,* (2019).

### 3.3.8. The impact access to financial services has on the acceptance of water management systems.

It has been noted that the availability of adequate finances encourages the acceptance of technology. A farmer's ability to access financial support services is speculated to promote the utilization of risk-borne innovative practices by removing financial constraints and enhancing households' capability to take a risk (Dhraief *et al.*, 2018). Thus, farming families can devote their resources on riskier yet profitable technologies rather than reducing risk by undertaking less risky activities (Akhtar *et al.*, 2019). However, it has been shown that the lending policies of some nations are discriminatory toward women, which prevents female-headed households from being able to finance yield-raising technology and lowers the rate of technology uptake (Muzari *et al.,* 2013; Aduwo *et al.,* 2017). Therefore, policymakers should enhance current smallholder financial support systems to ensure a greater range of farmers, predominantly women-led families, such that they may obtain loans (Mkandawire, 1993; Branca and Perelli, 2020). In some instances, this may require the creation of financial support systems that are specifically aimed at meeting the requirements of certain target populations (Aduwo *et al.,* 2017; Muzari *et al.,* 2013). For example, the Kenyan government launched an initiative to provide the youth and women with credit with no interest (Micheni, 2020). Thus, according to Micheni (2020), this may allow women to become more autonomous and adopt farming techniques, which would promote economic growth.

### 3.3.9. The impact of formal education on smallholder water management.

The educational level of the farmer is believed to exert a significant influence on their readiness to embrace innovative agricultural practices (Zhang *et al.,* 2019). The ability to access, comprehend, and implement agricultural innovations becomes more pronounced as a farmer's exposure to higher levels of formal education increases (Uduji, and Okolo-Obasi, 2018). This was proven in research done by Okunlola *et al.,* (2011) when examining factors influencing the level of adoption of fish farming technology in Akure, Ondo state, Nigeria. Ajewole (2010) as cited by Onwuaroh *et al.,* (2021) also found farmers' degree of educational attainment to align with the level of adoption when studying the elements influencing farmers' decisions to adopt organic fertilisers. Sennuga *et al.,* (2020) state that this is partly a result of the exposure that higher education has on the farmers' attitude towards new technology as education induces analytical, and rational thinking. This would result in a better understanding of the benefits of the new technology. Therefore, farmers possessing an advanced level of formal education can explore and accept new means of farming. While education is often touted for its positive role in facilitating technology adoption, it is essential to acknowledge that certain studies have shed light on the potential drawbacks of education in the context of farmers embracing new technologies (Prokopy *et al.,* 2019). Contrary to the conventional wisdom that educated individuals might be more inclined to adopt innovations, the degree of farmers' educational attainment can sometimes inadvertently hinder the pace of technology adoption. This phenomenon was illuminated in a comprehensive literature review conducted by Prokopy *et al.* (2019), which delved into the adoption of environmentally friendly preservative techniques within the agricultural landscape of the United States of America.

### 3.3.10. Age as a factor of the acceptance of formal water management systems.

Another factor used to predict the acceptance of innovative farming practices is age (Yigezu *et al.,* 2018). Older farmers who had accumulated knowledge, and experience can make sound assessments of the proposed innovation as compared with younger farmers (Yokamo, 2020). Moreover, age does not coincide with the acceptance of innovative agrarian practices all the time as Zhang *et al.,* (2019) state. Adesina and Zinnah (1993) are cited by Hu *et al.,* (2019) as they highlighted that, farmers are likely to avoid risk and long-term investments in their farming practices as they age. As opposed to older farmers, youthful farmers are eager to accept risk-prone practices and proposed innovation (Brown *et al.,* 2019). A notable illustration of how age impacts the adoption of new technology can be seen in a survey conducted by Alexander and Van Mellor in 2005 as cited by Agholor and Sithole (2020) which indicated that an increase in experience among younger farmers also intensified the rate at which genetically modified maize is adopted. Thus, the rate of adoption of genetically modified maize decreased as farmers edged closer to retirement (Alexander and Van Mellor, 2005; Agholor and Sithole, 2020).

### 3.3.11. Gender as a factor on the acceptance of formal water management systems.

The gender roles assigned by society seem can hinder the acceptance of proposed innovative agricultural practices or equipment, yet adequate data on the role gender plays in technology uptake is not available (Gebre *et al.*, 2019). A survey steered by Morris and Doss, (1999) when assessing the effects gender has on the acceptance of maize technology concluded which states that gender has little to no influence on the farmer's willingness to incorporate new farming methods or technology on the farm (Adams *et al.,* 2021). Access to resources was cited by Morris and Doss, (1999) to have a substantial impact towards the farmers' willingness to incorporate innovative practices rather than gender. Morris and Doss, (1999) went further to state that men are likely to accept innovative agrarian practices. This is due to immense access to resources men have compared to women resulting in the technology being of great benefit to men compared to their female counterparts (Sennuga *et al.,* 2020). Gender can influence technology adoption negatively provided the technology is labour intensive (Gebre *et al.,* 2019). In patriarchal societies, gender asserts a pivotal role in the uptake of innovation as men are regarded as the primary leader and decision-makers in a household. As a result, men are given sole access to resources vital for agricultural production compared to females owing to cultural and societal norms (Cecilia *et al.*, 2020). Research done by Obisesan (2014) supports the statement as cited by Ojeleye, (2018) on the adoption of an enhanced cassava cultivar suggest that gender had an impact on adoption. Obisesan's results were supported by a study conducted by Lavison in 2013 as cited by Chweya (2018) which found that the chance of male farmers to accept new farming practices was higher compared to female farmers.

### 3.4. Sustainable agricultural water preservation strategies.

Food security and agricultural efficiency is heavily reliant on irrigation water. Worldwide, irrigation farming account for twenty per cent of the global farmed land and forty per cent of food produced (Wang, 2022). Irrigated farming is efficient when compared to rain-fed farming systems as it can produce two times more food per land used than rain-fed systems (Morais *et al.*, 2021). It is of utmost importance that agricultural water-use be re-evaluated to ensure long-term sustainability and supply stability to cushion against climate change in the future.

### 3.4.1. The use of cover crops in limiting evapotranspiration.

The practice of using plant material as soil cover was termed "Mulching" by Singh and Agrawal (2020) as they explain that the word originated from the Dutch word "Molsch" denoting a soft decaying material. By minimizing erosion and soil degradation, weed infestation, and water evaporation, mulching slows down the deterioration of soil (Iqbal, *et al.,* 2020). Since this improves soil quality and increases minerals in the soil, it allows for greater soil moisture retention, aids in controlling temperature changes, and ultimately increases the development and yield of crops (Thakur and Kumar, 2021). Furthermore, it is said that in rain-fed environments, mulching increases production by more than half compared to no mulching (Soni *et al.,* 2021). Mulching is further divided into two groups: organic mulch and inorganic mulch.

A natural material which includes bark, wood shavings, twigs, withered grasses, and crop residues make up an organic mulch (Iqbal *et al.,* 2020). Organic mulch's drawback is that it draws insects, snails, and cutworms that devour them (Dhyani and Maurya, 2022). They easily degrade, as a result, necessitating frequent replacement. Gravel, pebbles, broken stones, and plastic are all utilized as inorganic mulch. Unfortunately, small rocks with a thickness of 3–4 cm help to prevent weeds but also reflect sunlight, which can make the soil extremely hot in the summer (Chopra and Koul, 2020). The production of plastic layers with photosensitive qualities that are best for a crop in a specific farm region is the consequence of advancements in plastic science (Khalid *et al.,* 2023). To use plastic mulch, agronomists ought to comprehend the ideal above- and below-ground conditions for a specific crop (Akhir and Mustapha, 2022).

### 3.4.2. Rainwater harvesting.

Man has attempted to exist in desert areas for several thousand years and has only been successful by skilfully managing that essential but limited resource (Yuan *et al.,* 2003). Water harvesting techniques that were previously created for survival are now being re-consideration since they can help boost water supplies for home and agricultural use (Kadigi *et al.*, 2019). Geddes (1979), cited by Myers (1975) and Yannopoulos *et al.*, (2019), provided the original definition of water harvesting as “the collecting as well as storage of every agricultural water, whether runoff or river flow, for agricultural use”. Currier's definition, "the technique for gathering natural rainwater through designated basins for productive utilisation," is also cited by Myers (1975) and Gorthi *et al.*, (2019). The concept of "collection of water from a region prepared to improve runoff from rainfall" was defined by Myers (1975) and Gorthi *et al*., (2019) explicitly. The definitions demonstrate that harvesting rainwater includes techniques for causing, gathering, and storing runoff from a variety of sources and for a variety of uses (Piemontese *et al.,* 2020). The techniques used vary significantly and are heavily influenced by the local environment. Some examples involve cultivating terraced beds, cultivating plants on micro-catchments, collecting runoff using sheet metal catchments, collecting subterranean runoff, and conserving runoff behind a reservoir, as well as other techniques (Chaplot *et al.,* 2018).

In Kenya, smallholder farmers primarily use two techniques for collecting rainfall: ex-situ and in-situ rainwater harvesting (Odhiambo *et al.*, 2021). Utilizing procedures which better the amount of water kept within the soil, in situ water collection techniques require capturing and utilising rainfall on the farm (Kugedera *et al.*, 2022). Popular methods include the utilization of ponds, contour bunds, and strip catchments (Mcharo and Maghenda, 2021). This technique also includes other conservation agriculture practices such as deep tillage and contour farming (Sarvade *et al.*, 2019). Collecting rainwater outside of a farm is known as ex-situ rainwater harvesting (Odhiambo *et al.*, 2021). For supplemental irrigation, the methods entail collecting and storing rainfall in ponds, wells, small earth dams, and other naturally occurring or artificial reservoirs such as water tanks of various shapes and sizes (Dwivedi *et al.*, 2021). Temporary storage facilities for use in arid environments may be an additional way of water storage in the future.

### 3.4.3. Irrigation water management.

There are several ways to categorize irrigation methods, including the amount of force or energy used, the location or method of applying irrigation water, and the area that is wetted (Dirwai *et al.*, 2021). The types of irrigation methods include flood irrigation, drip, or local irrigation (Drip Irrigation), and sprinkler irrigation, subject to the scale of the wetted surface area (Cetin and Akinci, 2021). Furrow, border, and basin irrigation make up flood irrigation, is the first of these methods (Abdelhafez *et al.,* 2019). The second method, drip irrigation, includes subterranean drip as well.

Water supplies are gradually running out owing to climate change and overuse, soil water storage has decreased, and soil degradation due to decreasing plant cover and secondary salinization has grown. These effects must be considered while managing irrigation systems (Corwin, 2021). Conventional or discarded knowledge can frequently be reincorporated further into the appropriate community to fight soil and land degradation; this is true for both rain-fed farming and conventional irrigation (Cuevas *et al.,* 2019). A downward spiral of water shortages and soil depletion resulted from improper land use and agricultural techniques paired with climate change (Islam *et al.,* 2020). Water supplies, soil water storage, and water for productive use are naturally constrained in dry regions and under actual water shortage circumstances, as shown in a study by Dolan *et al.,* (2021). Consequently, if this slow decline is to be prevented or even halted, managing these resources that have a direct effect on soil qualities including microclimates, should be of paramount importance.

### 3.5. Conclusion.

In conclusion, water-use efficiency is pivotal for sustainable agricultural methods and prudent management of the Earth's vital water resources. The integration of advanced technologies has been instrumental in boosting water-use efficiency in agriculture. Supported by agricultural extension services, these technologies empower farmers to make informed choices, optimizing water use for maximum crop yield. However, challenges exist in this transition. Socio-economic factors, limited access to technology, and inadequate infrastructure pose hurdles, exacerbated by regional and knowledge discrepancies.

Addressing these challenges demands a multi-pronged approach. Policy backing and investment are imperative to promote efficient water management practices and technological adoption. Enhancing agricultural extension services can bridge knowledge gaps, equipping farmers to tackle water scarcity. Achieving sustainable water-use efficiency requires cooperation among governments, experts, researchers, technology providers, and communities. By tackling constraints collectively and promoting water-efficient practices, the path is paved for a resilient, eco-conscious agricultural sector that safeguards water for current and future generations while ensuring global food security.

# 4. CHAPTER FOUR: THEORETICAL AND CONCEPTUAL FRAMEWORK

The conceptual and theoretical frameworks guiding the study are discussed in this chapter. The conceptual framework provided a foundation of understanding on the relationships between key concepts of the study. In contrast, the theoretical framework is more focused on testing and developing theories on technology adoption, the constraints hindering smallholder farmers in redesigning their production systems for water-use efficiency.

## 4.1. Conceptual framework.

For smallholder farmers particularly those situated in rural communities to adopt water-efficient farming methods and redesign their means of production to suit the changing climatic environment, socio-economic issues, and costs including risks of adopting the technology should be considered. Moreover, the farmers' willingness to incorporate new water-efficient farming practices within their production systems is dependent upon the cost-benefit ratio and the ease of using the technology as well as the stigma surrounding the new agricultural practices within the farming community (Nhone, 2020).

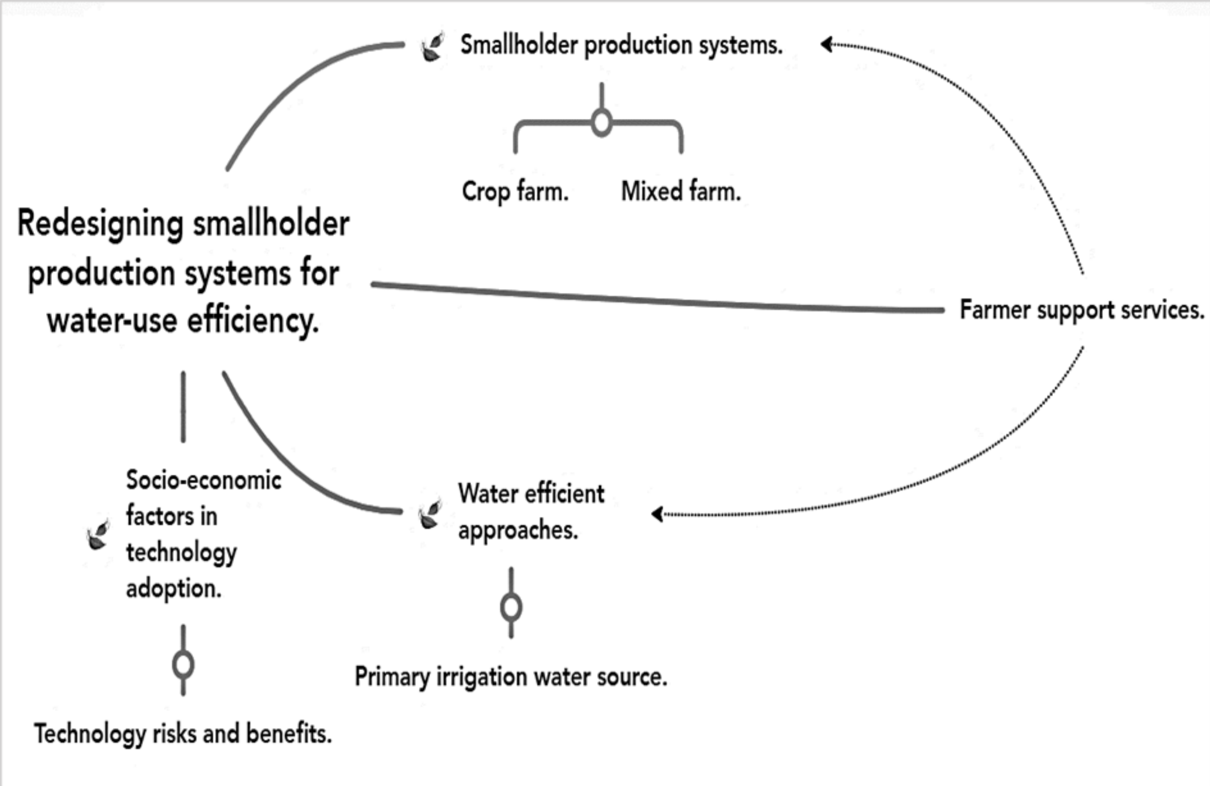



Figure 9: Encouraging WUE farming practices (conceptual framework).
Source: Own survey, 2023

The farmers' different production systems must be considered when designing new technology or innovative practices as this will ensure formal water management systems are accepted by smallholder farmers. Production systems differ depending on the farmer's natural assets or available resources and for the benefit of this study are as follows: crop farming system and mixed farming system. A crop farm or plant farm is limited to the production of vegetative crops, fruits including nuts, and a mixed farming system involves both livestock keeping and crop farming to diversify the farmer's produce and minimise risks as well as production costs (Adegbeye *et al.*, 2020). Hence, a farmer might consider venturing into a mixed farming production system due to the benefits associated with this farming approach as livestock defecates can be incorporated into the soil as fertiliser for the crop farming portion of this mixed farming production system. However, farmers may consider crop producing farming systems based on their access to vast amounts of land, reliable irrigation water, and demands for specific crops within the local market, access to extension services and financial support institutions.

Varying components of each farmer's production system such as the type of labour, source of irrigation water, access to credit and farmer support services, operational costs including risks tied to the innovative practices or technology might impinge on the smallholders' desire to accept the practices or technology. Therefore, for adoption to occur, the aforementioned factors should be prioritised and critically evaluated to ensure that the technology aligns with the production systems, farmers' needs, and their socio-economic issues.

Being able to acquire extension services is a pivotal element in the drive for increased technology adoption (Kumar *et al.,* 2018). Extension practitioners frequently ensure that smallholder farmers are aware of the presence, advantages, and proper utilization instructions for the innovation or equipment (Chao, 2019). Moreover, the primary duty of agricultural extension practitioners is to link farmers and users of agricultural innovative technology with the developers or researchers of such innovative technology (Liu *et al.,* 2021). Therefore, the cost associated with the transfer of innovative technology from the manufacturer of the technology to bigger and more diverse groups of farmers is lowered (Chao, 2019).

Production output is anticipated to grow with the heightened practice of sustainable irrigation by limiting water loss in the form of runoff, evapotranspiration, and weeds competing with cultivated crops for water. Approaches such as rainwater harvesting, mulching, micro-irrigation, and irrigation schedules, could ensure that irrigation water is sustained and available for future use. Moreover, the farming community and agricultural market's needs must be catered for in the farm planning processes such as the choice of cultivars planned for sale or consumption. Thus, the type of water management systems, approaches, and water sources must be taken into consideration to meet the desired cultivar's water requirements.

## 4.2. Theoretical framework

The research study is anchored within the theoretical structure of the Theory of Change (ToC), incorporating the Technology Acceptance Model (TAM). This framework delves into the behaviour of farmers (who are consumers of technology/innovation), exploring their patterns of accepting and using innovative agricultural practices or technology. Two of the theoretical models are explained in detail as follows:

### 4.2.1. Technology Acceptance Model.

The theory centred around the acceptance of new technology, widely recognized as the "Technology Acceptance Model (TAM)," was originally developed in 1986 by Fred Davis as part of his doctoral research as per Zarafshani *et al.*, (2020). Based on the model, the contemplated functionality and perceived user-friendliness appear to be the main factors that influence the prospective user's willingness to adopt new technology and redesign their production systems (Hung-Chou *et al.,* 2018). This model focus on the views of the targeted users of technology and the traits that define the model Zarafshani *et al.,* (2020). This implies that whilst the technological product producer believes the innovation to be practical and user-friendly, adoption of the innovative technology may only occur when targeted consumers share those sentiments with the manufacturer (Rezaei *et al.*, 2020).

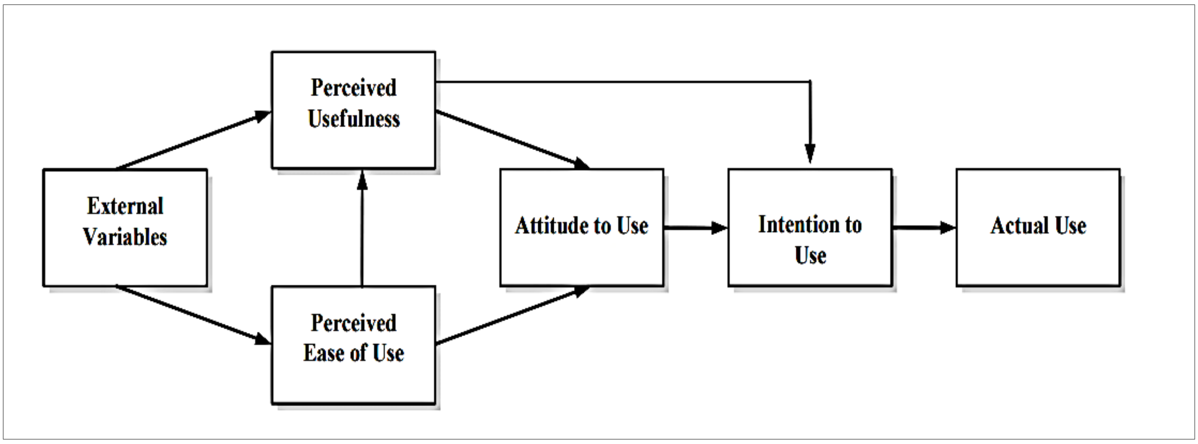



Figure 10: Illustration of the Technology Acceptance Model.
Source: Adeyinka, 2014.

Farmers must be interested in the technology's unique characteristics prior to their willingness to adopt the technology which in turn will aid in redesigning their production systems for WUE (Kernecker *et al.,* 2020). The farmers' readiness to adopt the suggested innovation is greatly influenced by their ability to test the technology on a small scale (Wang *et al.,* 2019. A study conducted by Mignouna et al. (2011) on the variables influencing farmers' acceptance of improved maize cultivars concluded that the distinct characteristics of the technology significantly affect farmers' decision-making. Prior to accepting the new technology, farmers should initially determine whether it is in line with their existing demands, environment, and future goals (Brown *et al.,* 2019).

The effectiveness of a new technology is factored in before farmers can accept the technology (Jha *et al*. 2019; Mohr and Kühl, 2021). In their 1993 review of the acceptance of contemporary rice crops, Adesina and Zinnah, (1993) found that farmers' perceptions of the traits of the new variety of rice influenced their readiness to adopt technology (AESON, 2012; Boateng *et al.,* 2022). Adesina and Zinnah (1993) arrived at the same result as Wandji *et al*. (2012) after investigating the views of farmers on the adoption of new aquatic farming methods in Cameroon (Obiero *et al.,* 2019; Rebecca, 2019; Kaee, 2019).

### 4.2.2. Theory of Change - Linear model.

The Theory of Change in relation to the adoption of agricultural technology serves as a framework delineating the anticipated causal connections between interventions and sought-after results (Adekunle and Fatunbi, 2014). It helps to clarify how specific actions and inputs lead to the intended changes in the context of adopting new agricultural technologies. This theory involves identifying key stakeholders, mapping out their roles and responsibilities, specifying the activities required for technology adoption, and predicting intermediate and long-term outcomes (Rice *et al.,* 2020). The theory illustrates the dynamics of social change by elaborating on the current perspective of the state, its root causes, the envisioned enduring reform, and the requisite alterations to facilitate the desired transformation, as indicated by Connell and Kubisch (1998). In the realm of agricultural research and development, articulating the Theory of Change is critical, as it unveils the rationale behind interventions and the trajectory of change within the system, as emphasized by Funnell and Rogers (2011). Guarneros-Meza *et al.*, (2018) suggest that building shared knowledge and encouraging group thought regarding the procedure required to bring about the desired change are other benefits of a clearly defined theory of change such as the following:

- Detect any possible flaws or shortcomings in our general understanding, including such theories or presumptions that should be examined, improved, or rejected.
- Create more logically sound theories of change that serve as the foundation for program initiatives.

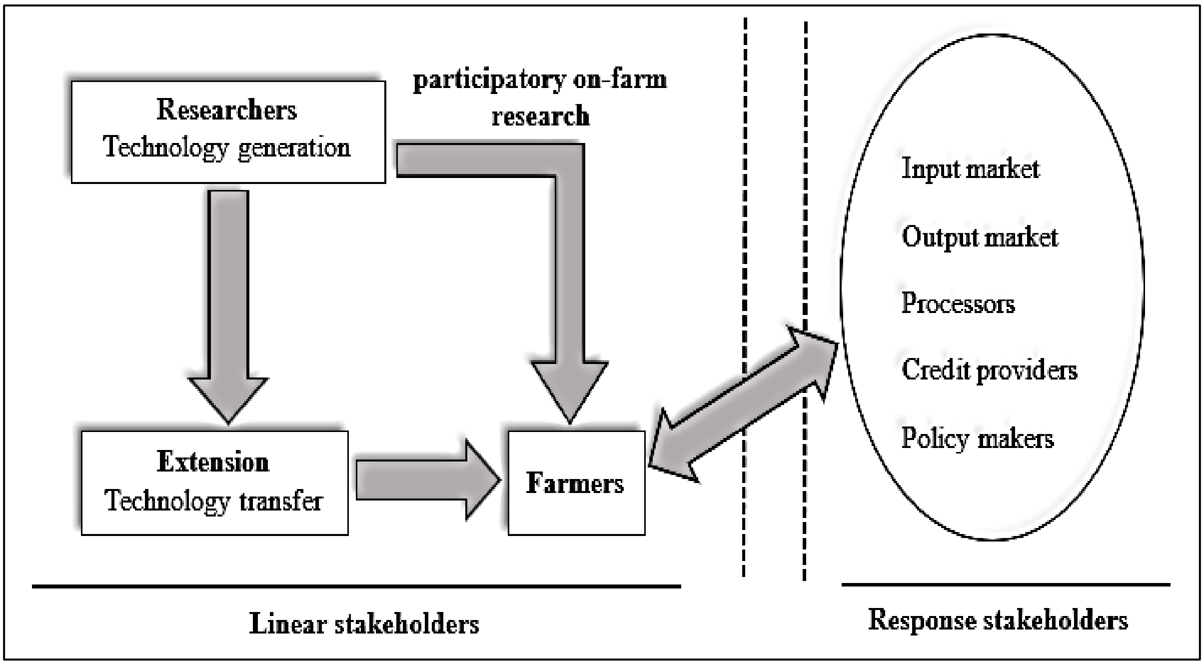



Figure 11: Schematic representation of the linear model.
Source: Adekunle and Fatunbi, 2014.

The linear model, often referred to as the "technology transfer" model, is a simplistic approach to agricultural technology adoption (Maru *et al.*, 2018). It assumes a straightforward, one-way process where new technologies are developed by experts and then transferred directly to farmers for adoption as shown in figure 12. In this model, the emphasis is primarily on the technical aspects of the technology itself, neglecting the social, economic, and contextual factors that influence successful adoption (Naidoo *et al.,* 2021). It often leads to a gap between the technology's potential and its actual impact on the ground. To address this limitation, modern approaches recognise the need for participatory methods, considering farmers' knowledge, preferences, and the local context to enhance the chances of successful technology adoption (Douthwaite *et al.,* 2020).

The theory of change- linear model has been used to study agricultural development in Africa (Agwu *et al.,* 2008). This model proposes that agricultural development follows a sequential trajectory, wherein farmers incrementally enhance their productivity and transition from subsistence farming to commercial farming. Hence, the model prioritised the research system, mainly on the creation of new technology to meet the demands of farmers (Adekunle and Fatunbi, 2014). Agronomy, pathology, and entomology studies, as well as other studies in the field of agricultural output, have been incorporated into the linear model with further advancement (Van de Fliert and Braun, 2002).

The idea that new technology is distributed to farmers via extension practitioners is fundamental to the linear model. The model has been criticised for its excessive simplification and its failure to account for the intricate dynamics of the African agricultural industry. The failure of this strategy to address Africa's difficulties was clear from the outset, particularly given how adamantly those issues remained and grew more so after the systematic structural meltdown among key institutions namely, the extension services (Thinda *et al.,* 2020). According to an evaluation of the concept, some noticeably positive outcomes were achieved on the continent up until the point where the farmer support service weakened as a function of institutional mismanagement and even a shortage of government involvement (Glover *et al.,* 2019). Following on this conclusion, efforts have been undertaken to improve this theory of change, leading to the establishment of "agricultural systems research" that examined the advancement of the system in its entirety as opposed to the growth of its components (Collazos *et al.*, 2021).

The implementation of farmer participatory research methodologies subsequently improves the degree of farmer engagement throughout the knowledge-creation process as a means of enhancing the acceptance of established techniques in the future (Adamsone-Fiskovica and Grivins, 2022). On-farm trials were first implemented with the presumption that since technologies were created in a closed environment and could not be adapted to farmers' actual environments, they would not be adopted (Richardson *et al.*, 2022). Additionally, to hide the apparent shortcomings of the natural link acquired from the actions of agricultural extension, the innovation effectively formed a channel which closely tied experts with farmers (Tufail *et al.*, 2020).

### 4.3. Conclusion.

In summary, the Theory of Change (ToC) offers a clear structure for understanding social interventions and technological adoption. While the linear model emphasizes cause-and-effect relationships, it may oversimplify real-world complexities. The Technology Acceptance Model (TAM) focuses on individual technology adoption factors yet overlooks broader contextual influences. Combining aspects of both models yields a more holistic view. Recognizing causality complexities and the interplay between perceptions and contexts enables more effective interventions. In our dynamic world, flexibility is key. Both ToC and TAM provide valuable guidance for researchers and practitioners seeking meaningful change and technology integration.

# 5. CHAPTER FIVE: METHODOLOGY

## 5.1. Study site.

Numbi is a rural community situated near the Numbi-gate Kruger National Park entrance and forms part of communities under the Mbombela Local Municipality, a local municipality in Mpumalanga province, South Africa. According to data extracted from Google Maps (2022), the geographic coordinates are 25°07'39.8"S 31°09'44.9"E. Figure 4 below depicts a map of the study area.


Figure 12: Map of Numbi.
Source: Google Maps, 2022; Municipalities of South Africa, 2022.

The statistical report compiled by StatsSA (2011), states that the size of the rural community is 4.57-square-kilometres comprised of 7,696 people and 1,932 households. Furthermore, the dominant racial group is Africans who make up 99 per cent of the community, and 94 per cent are of the Swati tribe (StatsSA, 2011). The main economic activity is farming with most of the households having backyard gardens consisting of seasonal crops, subtropical fruit trees and nuts such as macadamia.

## 5.2. Study population.

The rural community (Numbi) encompasses a modest population of nearly eight thousand individuals and 1,932 families (StatsSA, 2011). Most residents are engaged in the agricultural sector, with a smaller portion being smallholder farmers scattered throughout the community. Females constitute a slight majority of 53. 22% with males making up the remaining 46. 78% of the population (StatsSA, 2011). The population is mostly young with most residents being below 35 years of age relatively few above 60 years of age (StatsSA, 2011). The population according to StatsSA (2011) is 99% black with the other population groups such as white, coloured, Indian, or Asian constituting less than 1% of the community and the community is predominantly Swati speaking (93,72%) followed by Sotho (2, 24%), Tsonga (1,79%), Zulu (0,56%), English (0, 34%), and other South African official languages (1,35%).

## 5.3. Study design.

The study followed a quantitative approach, specifically employing a survey approach. A survey questionnaire was used to gather information from a participants included in the study sample. The survey data focused on participants' viewpoints regarding the enhancement of water-use efficiency in smallholder production systems, the utilization of water-efficient methods within the study area, challenges limiting farmers' capacity to restructure their production systems, and their willingness to embrace formal water management systems.

## 5.4. Sampling method and sample size.

In this study, a simple random sampling method was employed to select participants from the entire population of farmers, estimated to be around 217, out of which 67 are registered with the local Department of Agriculture (DARDLEA, 2022).and an estimated 150 are not registered. The sample size for this study consists of 141 respondents, determined using Taro Yamane's formula for sample size calculation. The equation is as follows:

$n$= Size of the sample (141) $N$= Total population (217) $e$= Margin of error (0.05)

$$\boldsymbol{n} = \frac{N}{1 + Ne^2}$$

$$\boldsymbol{n} = \frac{217}{1 + 217(0.05)^2}$$

$$\boldsymbol{n} \Rightarrow 140{,}6807 = 141\ farmers.$$

**5.5. Data collection.**

A structured questionnaire was utilized to gather quantitative data. This questionnaire was specifically designed to collect information relevant to the achievement of the study aim and objectives. It also aimed to assess the efficiency of production systems in terms of water use, identify the application of water-efficient approaches, explore challenges in reconfiguring production systems, and gauge the willingness to adopt formal water management systems.

**5.6. Data analysis methods.**

The data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 28. To achieve the research objectives and address the study questions, several methods were employed, including One-way Analysis of Variance (to assess the differences irrigation water source and the implementation of water-use efficiency approaches among smallholder farmers in the study area has on the acceptance of formal water management systems), and the Binary Logistic Regression (to determine farmers' intention to accept formal water management systems at the study area). Descriptive statistics were utilized, particularly to determine the mean, frequency, and standard deviation of the collected data in relation to farmer' challenges in accepting formal water management systems and the application of water-use efficiency approaches at the study area. The details of the analysis techniques are elaborated upon in sections 5.6.1 to 5.6.3 below.

### 5.6.1. Analysis of Variance.

The advantage of employing the one-way Analysis of Variance (ANOVA) lies in its capacity to facilitate the comparison of variability among two or more groups (Ross and Willson, 2017). The method of analysis consists of one independent variable which is the factor and has several different levels which correspond with the conditions under study. Hence, One-way ANOVA was employed to assess the differences irrigation water source and the implementation of water-use efficiency approaches among smallholder farmers in the study area has on the acceptance of formal water management systems. The following One-way ANOVA hypotheses was tested:

> $H_1$(Null hypothesis): $\mu_1=\mu_2= \mu_3=\ldots=\mu_k$(Irrigation water source influences the adoption of water-use efficiency approaches.).
>
> $H_0$(Alternative hypothesis): $\mu_1\neq \mu_2\neq \mu_3$(Irrigation water source does not influence the adoption of water-use efficiency approaches).

Numerous authors such as Mariappan and Zhou (2019), and Palii *et al.*, (2021) have used the one-way analysis of variance (ANOVA) in their studies. Mariappan and Zhou (2019) used the method when comparing variability among the profitability of organic rice production and conventional rice production. In their study, Palii *et al.*, (2021) employed one-way ANOVA to assess the differences in milk protein content and yield across various cattle breed combinations.

#### 5.6.1.1. Explanation of the variables being compared in the study.

The variables used to compare variance between irrigation water source (independent variable) and the application of water-use efficiency approaches are described below.

**i. Irrigation water source.**

The act of adding water to the soil artificially with the sole purpose of complying with crop water requirements is referred to as irrigation (Ofualagba, 2019). Therefore, irrigation water source refers to the primary means of accessing irrigation water such as a river, municipal water, surface water, borehole (well), and rain (Ruess *et al.,* 2023).

**ii. Water-use efficiency approaches.**

Agriculture methods concentrated on using management techniques to boost transpiration and minimise water wastage due to evaporation, and runoff (Panigrahi *et al.,* 2021). Examples include the use of conservation tillage, early planting, cultivars with quick early growth, and the combination of plant population and row spacing.

### 5.6.2. Descriptive statistics.

Descriptive statistics is beneficial to summarise and explain data in way that is easy to understand and visualise by a person reading the study analysis (Carroll *et al.,* 2020). Additional advantages linked to the utilization of descriptive statistics include the ability to discern patterns, trends, and relationships within the data. Moreover, the descriptive analysis method can aid in identifying outliers, bias, improve accuracy, and potential analysis errors. Descriptive statistics, notably mean, frequency, and percentage, were applied to ascertain the adoption of water-use efficiency approaches by smallholder farmers in the study area. Additionally, descriptive statistics were used to characterize the socioeconomic attributes of smallholder farmers and to outline the production systems they employed in the study area.

### 5.6.3. The model adopted for the study.

The adoption of formal water management systems in the study area was assessed using the binary logistic regression model. Binary logistic regression as a statistical tool is best suited for analysing relationship between a binary dependent variable (which has only two possible outcomes) and one or more independent variables (Marie *et al.,* 2020). Additionally, regression models are used to assist in estimating the probability of events based on the collective function of variables speculated to affect an outcome (Miceli *et al.*, 2008). Currently, logistic regression is widely used in studies assessing the rate of technology acceptance and its determinants. Most researchers use the model to categorise people into a single group or two groups only when a single set of variables hypothesised to predict adoption is available, and aid in the discovery of qualities or attributes which best predict decision making (Harper, 2005; Sithole, and Agholor, 2021). The distribution of predictor variables (X) is not assumed; however, these variables can be either discrete or continuous. The model's credibility is well-regarded in empirical studies aimed at identifying factors that influence decision-making, especially the adoption of technology by its intended users. in similar studies, Al-Qerem, and Jarab, (2021) used the binary logistics regression model in their study focusing on the acceptance of Covid-19 vaccines. Similarly, Adams *et al.,* (2021) used the binary logistics regression model in their analysis of the viability and selection of marketing channels in the tomato farming sector of Ghana.

The current study investigated the link between the demographic attributes of smallholder farmers and their acceptance of formal water management systems in the study area. Logistic regression is believed to be the optimal method when there is a combination of numerical and categorical data. Indicated below is the approach utilised to identify acceptance behaviour:

$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \beta_{11} X_{11} + \mu \ldots\ldots\ldots\ldots\ldots$

Where:

Y = Intention to accept formal water management systems (Dependent variable).

$X_1 - X_{11}$ = Independent variables demarcated as follows:

$X_1$ = Gender.

$X_2$= Age.

$X_3$ = Education level.

$X_4$ = Farming experience.

$X_5$ = Farm size.

$X_6$ = Household size.

$X_7$ = Farmer support services.

$X_8$ = Alternative irrigation.

$X_9$ = Farming methods.

$X_{10}$ = Subsistence farming practice.

$X_{11}$ = Off-farm activities.

$\beta_0$ = constant.

$\beta_1 - \beta_{11}$ = standardized partial regression coefficients

μ = error term

**Predictor variables as hypothesised to influence the acceptance or adoption behaviour.**

**i. Gender.**

The gender roles imposed by society appear to be impeding the adoption of innovative agricultural methods, and various scientists have concentrated on this issue (Udimal *et al.,* 2017). Morris and Doss (1999) states that males are more likely to embrace novel agricultural methods because they have more access to resources than women, resulting in the technology being more beneficial to men than to women (Sennuga *et al.,* 2020) According to Morris and Doss (1999), access to resources exert a greater effect on farmers' willingness to accept new techniques of farming. In this study, gender is anticipated to exert a positive or negative impact on the acceptance of formal water management systems, as illustrated in table 2 below.

**ii. Age.**

Age is another factor used to predict the acceptance of formal water management. Studies have shown that age as a demographic variable influences the adoption of technology (Bannor *et al.*, 2020). In this current study, age was hypothesised to not always correlate with the acceptance of agricultural innovation.

**iii. Educational level.**

The higher the level of formal education a farmer has, the better equipped they are to access, understand, and implement agricultural innovations (Hyland *et al.*, 2018). According to Llewellyn and Brown (2020), exposure to higher education positively influences farmers' attitude towards new technology, given that education enables them to be more analytical, logical, and aware of the advantages of the new technology.

**iv. Farming experience.**

Farmers learn skills throughout the years and gradually transition from conventional agricultural technology to new technologies based on observed productivity and having to learn upon the acquired skills (Ainembabazi and Mugisha, 2014). Farming expertise is valuable in the earliest stages when new technology is introduced as farmers are still exploring its distinct advantages (Takahashi *et al.*, 2020).

**v. Farm size.**

Technologies that depend on size can only be applied to larger plots of land compared to smaller ones. Farmers with larger farm sizes have the advantage of allocating sections of their land for experimenting with new methods, in contrast to those with smaller plots (Hu *et al.*, 2019). Moreover, the profitability of using mechanical equipment or animal traction relies on the farm size (Daum *et al.,* 2022).

**vi. Household size.**

Household size can be a significant labour supply source that may also affect adoption choices. According to Ndiritu *et al.,* (2014), farm households with more members are likely to indulge in more physically demanding activities. Composites of a household's assets indicate wealth position, the ability to purchase contemporary goods, and the ability to hire labour for manufacturing tasks (Oyetunde-Usman *et al.,* 2021). A larger household may also affect a household's wealth position negatively as there are more individuals reliant on a limited stream of income.

**vii. Farming methods.**

The term "farming methods" refers to the process of cultivating crops on land that has undergone extensive cultivation and tilling, such as irrigating, ploughing, or turning the soil, and where all weed development is continually suppressed for the sole purpose of growing crops such as cabbage, tomatoes, grain, and legumes (Ofstehage, and Nehring, 2021). Hence, in this study, the impact of agricultural techniques on the acceptance of formal water management systems is expected to be either favourable or unfavourable.

**viii. Subsistence farming practice.**

Subsistence farming is an agricultural practice in which the produce or animals grown serve the nutritional needs of the farmer's household, leaving little or no excess for market or trade (Dodd *et al.,* 2020). Therefore, the engagement in subsistence farming within this study is anticipated to have no effect on the adoption of formal water management systems.

**ix. Alternative irrigation.**

Artificially applying water to land is known as irrigation. Some land must be irrigated before it can be used for any agricultural purpose (Kireva, and Mihov, 2019). In certain areas, irrigation is primarily used to supplement rainfall and boost output. Naturally, not all land requires irrigation, however it can positively influence the acceptance of formal water management systems at the study area.

**x. Farmer support services.**

Refers to services provided to smallholder farmers to guarantee awareness of the availability, advantages, and proper use of the invention or equipment. In addition, agricultural extension practitioners' major responsibility is to serve as a conduit between the innovators of new agricultural technologies and the farmers and other end users of such technologies (Mapiye *et al.*, 2021). Hence, farmer support services are thought to influence the acceptance of formal water management systems at the study area.

**xi. Off-farm activities.**

It has been determined that adoption of suggested new agricultural methods or equipment benefits from off-farm earnings (Halloran *et al.*, 2021). This is so that families in several developing countries will be able to exceed their credit limitations by using off-farm income (Do *et al.*, 2022). Off-farm income is apparently utilised to replace borrowed cash in farming communities lacking or with dysfunctional financial markets. Off the farm activities are projected to boost farmers' access to capital for spending in production-enhancing inputs. (Mazibuko *et al.*, 2018).

**Table 1: Independent variables hypothesised to influence adoption behaviour.**

| Variable & Code. | Operational variables. | Measurement unit. | Expected sign. |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Gender (GDR). | A social and cultural construct for being male or female. | Male =1, Female=2 | +/- |
| Age (AGE). | The amount of time in years a person has lived. | 20-29 years=1, 30-39 years=2, 40-49 years=3, 50-59 years=4, ≥60 years=5 | - |
| Education level (EDU). | Exposure to formal learning environment. | No school=1, Primary school= 2, Secondary school= 3, post-secondary school= 4 | + |
| Farming experience (EXP). | Number of years a farmer has been practicing farming. | ≤1 year=1, 2-5 years=2, 6-9 years=3, 10-13years=4, ≥14 years=5 | + |
| Farm size (SIZ). | The total size of cultivated land. | ≤1 acre=1, 2-4 acres=2, 5-8 acres=3, 9-12 acres=4, ≥13 acres=5 | + |
| Household size (HHS). | The number of individuals residing in the household | Not in a household=1, 2-5 people=2, 6-8 people=3, 9-11 people=4, ≥ 12 people=5 | - |
| Farming methods (MET). | Methods used to cultivate crop or manage the farming system. | Organic farming=1, Shifting cultivation=2, crop rotation=3, Intercropping=4, Inorganic farming=5 | +/- |
| Subsistence farming practice (SUB). | Growing crops for the sole purpose of feeding a farmer’s households and in some instances, the surplus produce is sold. | Yes=1, No=2 | - |
| Alternative irrigation (IRR). | The use of additional irrigation water to supplement crop water shortages owing to low precipitation. | Yes=1, No=2 | + |

| | | | |
|---|---|---|---|
| Farmer support services (FSS). | Farmer support from government | yes=1, No =2 | + |
| Off-farm activities (OFA). | Revenue generated from off-farm related activities. | Employed=1, off-farm business=2, Social grant=3, Pension=4, None=5 | + |

### 5.7. Ethical considerations.

The formulation of the dissertation work considered ethical principles including decency, objectivity, compassion, and anonymity. Participants' privacy and opinions on their involvement in the study endeavour were respected and safeguarded by keeping their names, contact information, and other identifying information private. Notwithstanding gender, nationality, background, or personality features, the researcher was objective towards the individuals by acting without prejudice. Consequently, when they asked about the advantages and goal of this study, it was clearly stated. To prevent forced involvement or the imposition of harm to the farmers, they were informed that participation is not compulsory and may leave the research at any moment they feel uncomfortable. To conclude, ethical clearance was awarded by the University of Mpumalanga’s research ethics committee with reference UMP/Morepje/201503045/MAGR/2023 for this study.

### 5.8. Conclusion.

In summary, the methodology section lays the foundation for this dissertation's research. The study site, population, sampling, and sample size decisions are tailored to the research goals. Data collection methods align with research questions, ensuring relevant insights. Analysis tools are chosen purposefully, bolstering result interpretation. Ethical considerations are threaded throughout, prioritizing participant rights and confidentiality. Ultimately, this wellcrafted methodology promises to yield valuable, credible insights that contribute meaningfully to the field's knowledge.

# 6. CHAPTER SIX: RESULTS AND DISCUSSION

This section unveils the outcomes of the study assessing the socioeconomic aspects of farmers, the production techniques employed by smallholder farmers, impediments, and difficulties in assessing the determinants of farmers acceptance of formal water management to enhance water-use efficiency, as well as the strategies employed by smallholder farmers to enhance water-use efficiency.

## 6.1. Socioeconomic features of smallholder farmers at the study area.

This part of the results and discussions concentrates exclusively on socioeconomic factors of farmers, including age, gender, level of education, farming experience, farm size, household size, availability of farmer support services, access to alternative irrigation water, farming techniques, and off-farm engagements. The outcomes were analysed through descriptive statistics and are visualized using pie charts, tables, and column diagrams that elucidate the statistical details of both categorical and numerical variables.

### 6.1.1. Distribution of farmers by gender in the study area.

Illustrated in Figure 14 the breakdown of farmers by gender within the study area. Female farmers constitute the majority, accounting for 62.4% of the sample, while male farmers make up 37.6% of the sampled population. Thus, women hold the predominant role in the smallholder production systems within this study area. In the context of smallholder farming communities, the implications of having a higher proportion of females compared to males extend to the acceptance of formal water management systems. Gender dynamics within such communities significantly influence decision-making processes regarding water resource allocation and management (Zwarteveen and Mollinga, 2011). Women, who often constitute a substantial portion of the agricultural workforce, are traditionally involved in various aspects of farming, including water management (Doss *et al*., 2014).

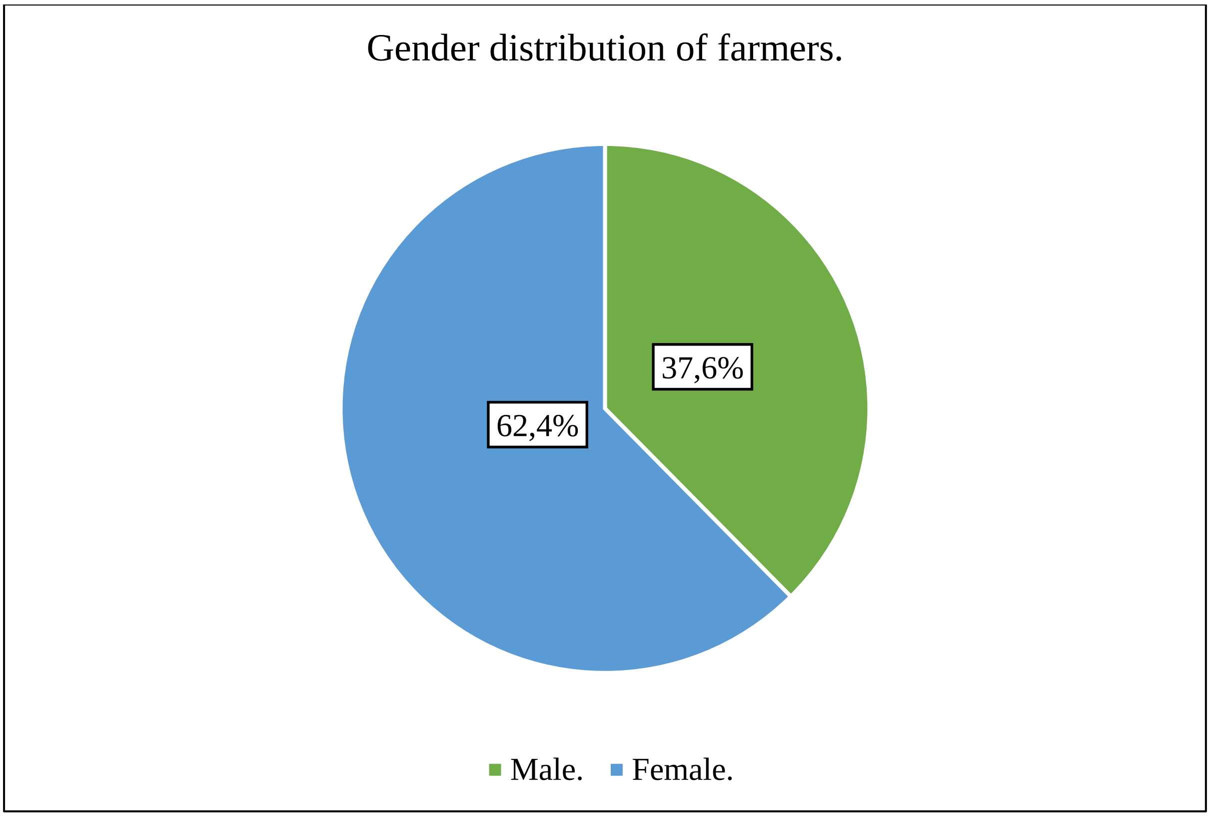



Figure 13: Gender distribution of farmers at the study area.
Source: Own survey, 2023.

Their roles and responsibilities in agricultural production, however, are frequently constrained by limited access to resources such as land, water, credit, and extension services (Doss *et al.*, 2014). Consequently, addressing gender disparities in resource access and participation is crucial for ensuring equitable adoption of formal water management systems (Hirons *et al*., 2018). Moreover, cultural norms and societal expectations may further influence women's ability to engage in decision-making processes related to water management (Bjornlund, 2015). Promoting women's empowerment and challenging existing gender biases are essential strategies for enhancing the acceptance and effectiveness of formal water management systems within smallholder farming communities (Hirons *et al*., 2018; Zwarteveen and Mollinga, 2011).

### 6.1.2. Distribution of farmers by age in the study area.

The findings depicted in Figure 15 reveal that most farmers in the study area, comprising 39.7%, are aged over 60. In contrast, farmers between the ages of 20 and 29 are in the minority, constituting only 9.2% of the total, with the remaining 51.1% is distributed among three other age groups: 30-39 years, 40-49 years, and 50-59 years, respectively. Consequently, the population of farmers in the study area can be characterized as predominantly middle-aged to elderly. In accordance with Elahi *et al.,* (2022), an older farming population is less likely to embrace risky or novel agricultural technologies when compared to younger farmers.

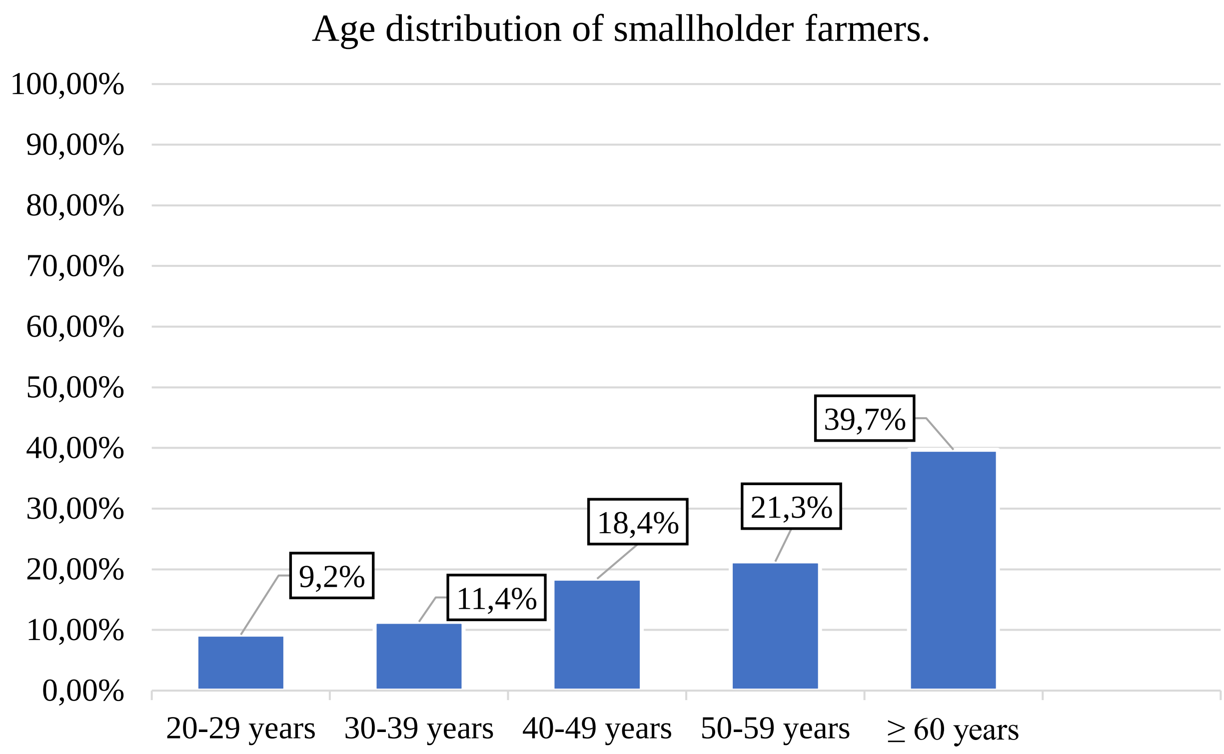



Figure 14: Age distribution of smallholder farmers.
Source: Own survey, 2023.

Moreover, elderly farmers have the capacity to critically assess the benefits and associated risks of adopting new farming practices in comparison to younger inexperienced farmers (Elahi *et al.*, 2022). Contrary to Elahi *et al.* (2022), Gao *et al.*, (2020) states that when put against younger farmers, elderly farmers are better equipped to evaluate new technologies since they have more knowledge and experience. Hence, farmers within the study area possess the capability to evaluate the utility of new technologies based on their knowledge and experience, as emphasized by Gao *et al.* (2020). Nevertheless, this knowledge and experience might lead farmers in the study area to be cautious about embracing precarious and enduring investments in their agricultural practices as they grow older, contrasting with the inclinations of younger farmers (Akaka *et al.,* 2023; Mendes *et al.,* 2023). Hence, age does not always correlate with the acceptance of innovative agrarian practises. In conclusion, the chances of risky technology being adopted at the study area are low as per Mendes *et al.,* (2023).

### 6.1.3. Categorisation of smallholder farmers based on their educational attainment.

The findings presented in Table 3 illustrate the educational levels of respondents in the study area. Approximately 42.6% of farmers possessed formal secondary school education, whereas 27.7% of farmers had completed formal primary school education. A minor 9, 2% of farmers have post-secondary school education exposure with 20, 6% of farmers never been through the formal education system. The educational level at the study area is satisfactory as most of the farmers attended formal education till the secondary school where a learner is expected to read, write, and interpret literature. Therefore, farmers will be able to read literature and instructions on the use of new technology.

**Table 2: Categorisation of smallholder farmers based on educational level.**

| | **Frequency** | **Percent** |
|---|---|---|
| No school | 29 | 20.6 |
| Primary school | 39 | 27.7 |
| Secondary school | 60 | 42.6 |
| Post-secondary school | 13 | 9.2 |
| **Total** | **141** | **100.0** |

Source: Own survey (2023).

The level of exposure to formal education has an influence towards a farmer's desire to use innovative agricultural techniques (Omar, Yap, Ho, and Keling, 2022). Furthermore, the more a farmer has been exposed to a higher degree of formal education, the more likely is the farmer able to access, comprehend, and apply agricultural innovation (Kendall *et al.,* 2022). Higher education has a positive effect on farmers' attitudes about new technology as it helps farmers become more analytical, logical, and aware of the advantages of the new technology (Qiao *et al.*, 2022).

#### 6.1.4. Distribution of farm experience among smallholder farmers.

Figure 16 showcase the distribution of farm experience among smallholder farmers at the study area. A significant majority, 39.0% of the interviewed farmers, have accumulated over 14 years of farming experience, while the smallest group, at 6.4%, comprises those with less than one year of farming experience. Additionally, 54, 7% of farmers have between 2-13 years of experience suggesting that the farmers in the study area are adequately experienced, making it easier for new technology to be adopted.

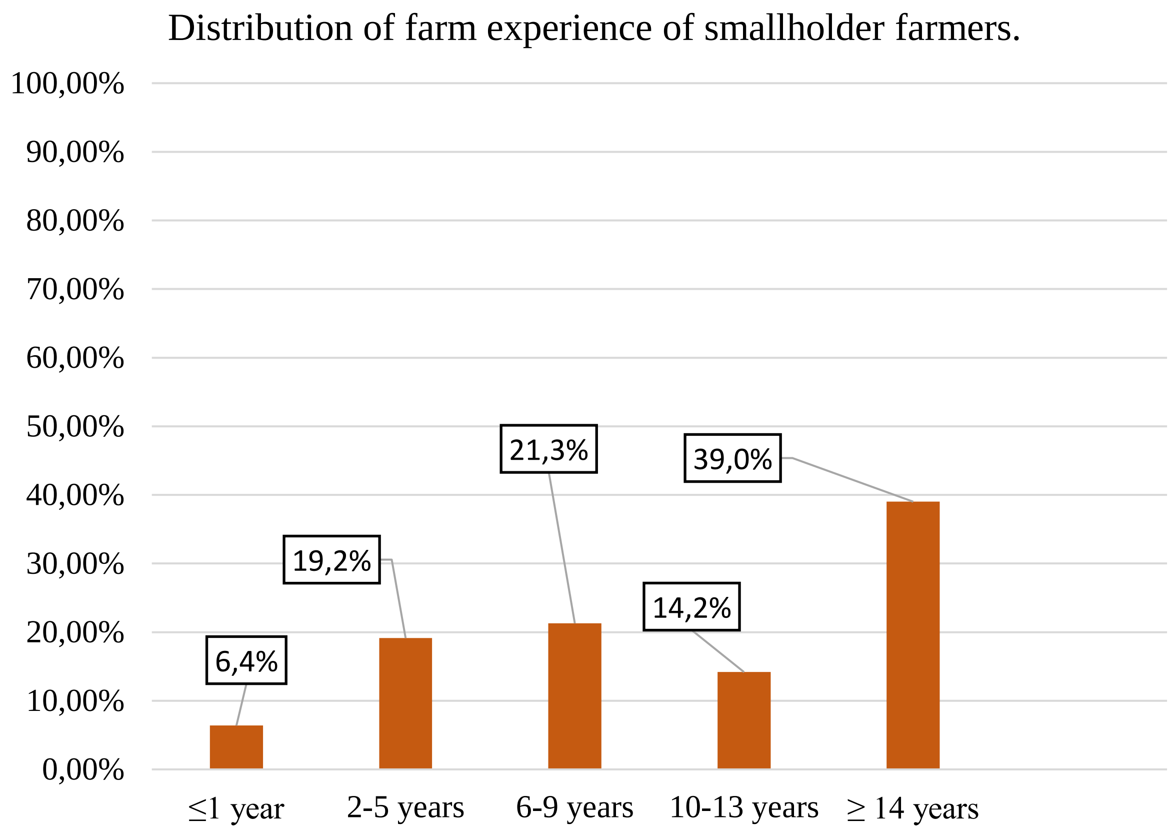



Figure 15: Distribution of farming experience of smallholder farmers.
Source: Own survey, 2023.

According to Chavas and Nauges (2020), it was observed that the productivity and the need to learn by doing, farmers gradually switch from traditional technology to new technologies as they gain new skills over time. Farming experience is most beneficial when a new developed technology is introduced as farmers can assess its unique benefits and risks by applying past experiences gained on prior technologies (Mao *et al.*, 2019).

### 6.1.5. Breakdown of smallholder farmers by their farm sizes.

The distribution of smallholder farmers according to their farm sizes is presented in Figure 17. From the survey sample, a 44, 7% majority of farmers are within the farm size range of 5-8 acres followed by 25, 5% of farmers with less than an acre of farmland. Moreover, 24, 1% of farmers are within the range of 2-4 acres and farmers with the least farmland makeup 5, 7%. Therefore, the size of production systems at the study area is large enough to allocate some portions of the farmland to testing new technology.

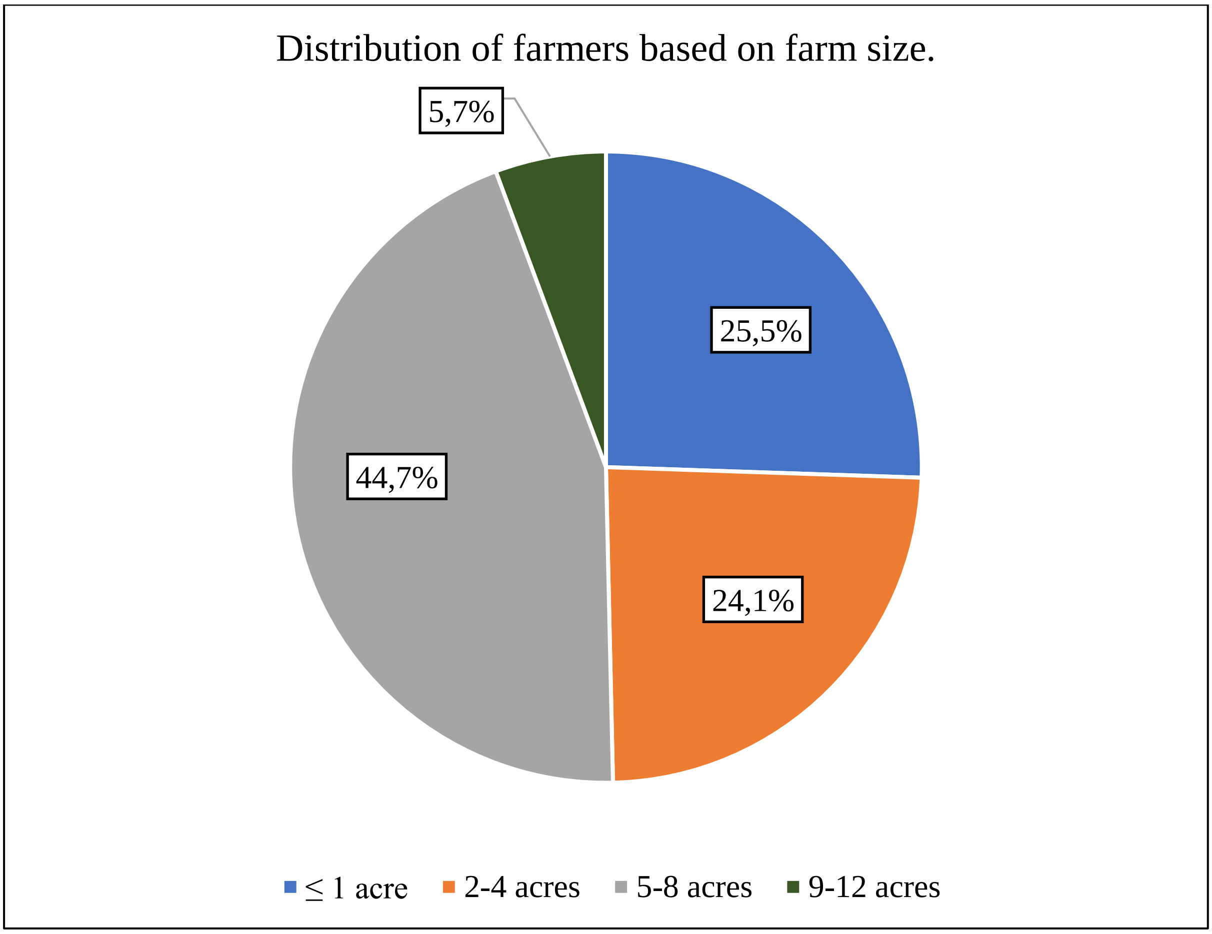


Figure 16: Categorisation of smallholder farmers by farm size.
Source: Own survey, 2023.

In addition to some adoption factors having a negative impact on farm size, farm size greatly impacts technology uptake both positively and negatively. When compared to smaller farms, size-reliant technology can only be used on larger farms (Gao *et al.*, 2020). Hence, farmers can only adopt farming technology that is not size reliant such as large machinery. Other farmers have an edge over those with smaller farms since they can allocate more of their land to testing out new techniques (Caffaro, and Cavallo, 2019). However, Despotovi *et al.*, (2019) state that farm size has little impact on other farming methods, such as integrated pest management (IPM).

### 6.1.6. The distribution of smallholder farmers categorized by their household sizes.

The table 4 showcases the distribution of household sizes among smallholder farmers within the study area. Household size is a significant labour supply alternative that may also affect adoption choices. The majority (39, 0%) of farmers live in households comprised of 6-8 household members. A minor 0, 7% of the farmers live alone or in households consisting of 1 member. Those who are between the range of 2-5 members makeup 33, 3% of the total sample of farmers with those having more than 8 members making a combined (9-11 members and ≥ 12 members) percentage of 26, 9%. This suggests that most smallholder farmers have adequate human resource for labour-intensive technology or farm activities.

**Table 3: Distribution of smallholder farmers according to household size.**

| | **Frequency** | **Percent** |
|---|---|---|
| Not in a household. | 1 | 0.7 |
| 2-5 Members. | 47 | 33.3 |
| 6-8 Members. | 55 | 39.0 |
| 9-11 Members. | 24 | 17.0 |
| ≥12 Members. | 14 | 9.9 |

| | | |
|---|---|---|
| **Total** | **141** | **100.0** |

Source: Own survey, 2023.

The adoption of labour-intensive sustainable practises is more likely to occur in farm households with more members (Cherono, 2019). Earlier, Mugi-Ngenga *et al.*, (2016), stated that smaller family sizes are linked to low rates of adoption when studying the social and economic aspects affecting the adaptability of households to climate change in arid regions of Kenya. Moreover, this is due to the low resource demand of smaller households such as food compared to larger households where expenses are expected to be higher and affect the overall household income negatively as per Nkambule, (2022).

### 6.1.7. Distribution of smallholder farmers based on farming methods practiced.

The results in figure 18 showcase the distribution of farmers based on farming methods. The most preferred farming method at 41, 1% is the application of animal manure as a fertiliser source followed by shifting cultivation at 25, 5%. Intercropping is at 5, 0% while both crop rotation, and inorganic farming makeup 28, 4% of approaches applied at the study area. In conclusion, organic farming is the widely preferred farming method amongst smallholder farmers at the rural community.

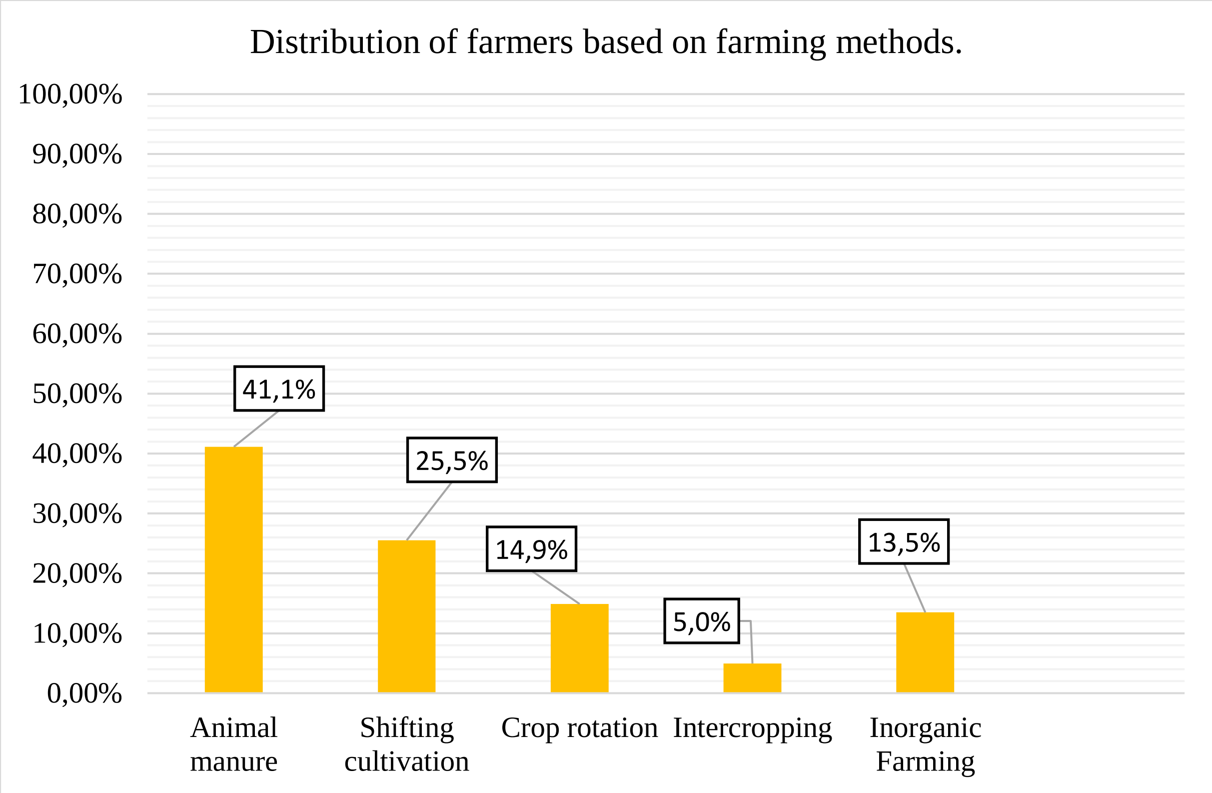



Figure 17: Distribution of farmers based on farming methods.
Source: Own survey, 2023.

Organic farming possesses the potential to enhance soil structure, elevate water retention capacity, mitigate erosion, and reduce the leaching of essential soil nutrients (Malik *et al.*, 2022). Additionally, a multitude of agricultural practices can facilitate biological, physical, and chemical transformations within the soil, leading to enhanced water retention and increased plant resilience against droughts, floods, and other extreme weather occurrences (Oladosu *et al.*, 2022). Furthermore, research has indicated that practices such as no-till cultivation, cover cropping, and crop rotations can intermittently enhance soil carbon levels, bolster soil biological activity, and improve soil physical attributes linked to water retention, as documented by Freidenreich *et al.*, (2022). Hence, engaging in perennial planting and creating diverse landscapes through crop rotation practices or integrating crop and animal activities can yield similar soil benefits, as highlighted in a study by Duchene *et al.*, (2019). This is due to such methods supplying the soil with the necessary protection from above- and below-ground vegetation, as well as the year-round incorporation of roots (Duchene *et al.*, 2019). Pasupulla *et al.,* (2021) state that organic farming preserves and promotes soil, animal, plant, and human health in addition to enriching and supporting biodiversity and ecological systems. Briefly, it also provides a balanced nutrient cycle, mineralization, and beneficial microclimatic regimes, which lowers risk for farmers.

### 6.1.8. Distribution of smallholder farmers based on subsistence farming practice.

Table 5 displays the distribution of smallholder farmers according to their farming practices. Whilst 85, 8% of farmers practice subsistence farming, only 14, 2% of farmers are not farming for the sole purpose of producing food for their households but to also sell their surplus to the informal market mainly within the rural community. The rationale behind the results showing a strong involvement of farmers in subsistence agricultural production is the lack of economic opportunities and poor living standards in the rural community. Thus, the food produced by the smallholder farmers is used to meet household nutritional needs and the surplus is sold locally.

**Table 4: Distribution of smallholder farmers based on subsistence farming practice.**

| | **Frequency** | **Percent** |
|---|---|---|
| Yes | 121 | 85.8 |
| No | 20 | 14.2 |
| **Total** | **141** | **100.0** |

Source: Own survey (2023).

In addition to enhancing livelihoods and assisting in the mitigation of excessive food price inflation, subsistence farming is crucial in lowering the risk of household food shortage amongst rural and urban communities (Jonah and May, 2020). In the study area, farmers engage in cultivating maize during the rainy seasons. Subsequently, the harvested maize is stored for diverse purposes that align with the specific needs of each farm household. The maize is turned into a maize meal (milled into powder or smaller granules) when the kernels are dry and while soft, it is turned into a paste which is mixed flour and other ingredients to make maize bread.

To guarantee long-term food security, subsistence farming must be much more effective; this can be accomplished by motivating farmers to seek production intensification that is sustainable and is based on the use of better inputs (Kuyah *et al.,* 2021).

### 6.1.9. Smallholder farmers' distribution by alternative irrigation use.

The findings in figure 10 depict that 87, 9% of farmers at the study area are applying additional irrigation water artificially to meet their crops' water requirements. Only a few (12, 1%) of the farmers do not supplement the shortfall of rain or seek alternative irrigation methods for their farms. This approach results in such farmers becoming solely reliant on ground water, rainfall, and soil moisture for most of their irrigation water needs. Moreover, the water used to artificially irrigate farms is mostly from municipals sources supplied for domestic use.

Subsequently, water is stored in tanks and on-farm ponds at the study area from several sources, including wells, municipal derived water, rainfall, and water streams to be later dispersed across the farm manually with watering cans. Hence, this suggests that smallholder farmers can meet most of their crops' water needs at the study area.

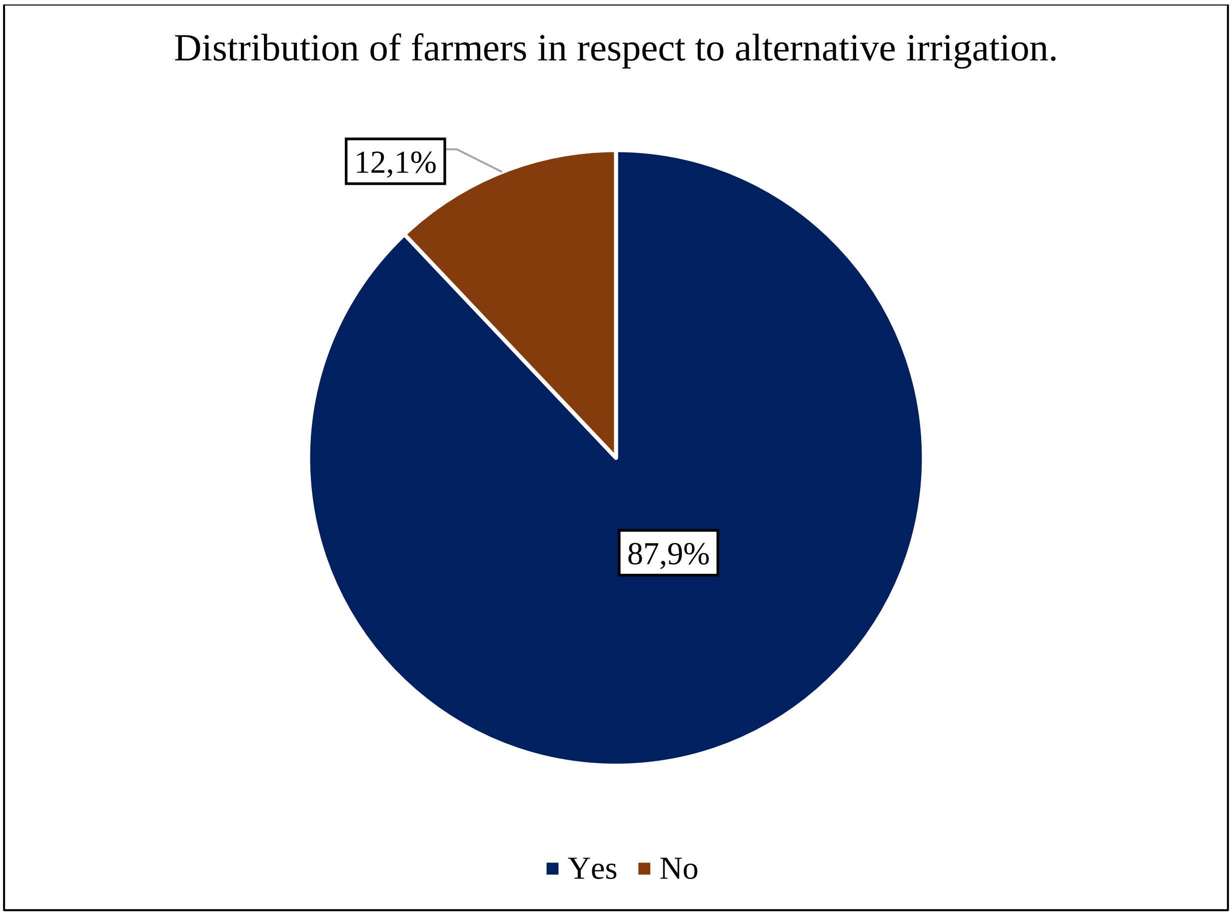



Figure 18: Distribution of farmers in respect to alternative irrigation.
Source: Own survey, 2023.

Although rainfall dependence reduces the risk of agricultural produce contamination, however, inconsistent weather patterns could interfere with agricultural production (Wenxin *et al.*, 2022). Thus, owing to the swiftly changing climate, water shortages have become a widespread problem, and droughts are occurring more frequently in South Africa (Orimoloye *et al.*, 2022). Nevertheless, using alternative irrigation water to replace rainwater, raises the possibility of contamination at the farming field due to water pollutants (Ripanda *et al.*, 2021).

### 6.1.10. Support smallholder farmers received from government.

Most farmers (comprising 58, 2% of the study population) support from the state in the form of fertiliser, seeds, irrigation equipment, agricultural training, and agricultural grants in the form of vouchers and fences to secure their farming fields. Only 41, 8% of farmers are self-reliant and/or have never received any agricultural support compared to many farmers who are supported through public or private initiatives to overcome challenges. The findings serve as a testament to farmers' access to extension support services.

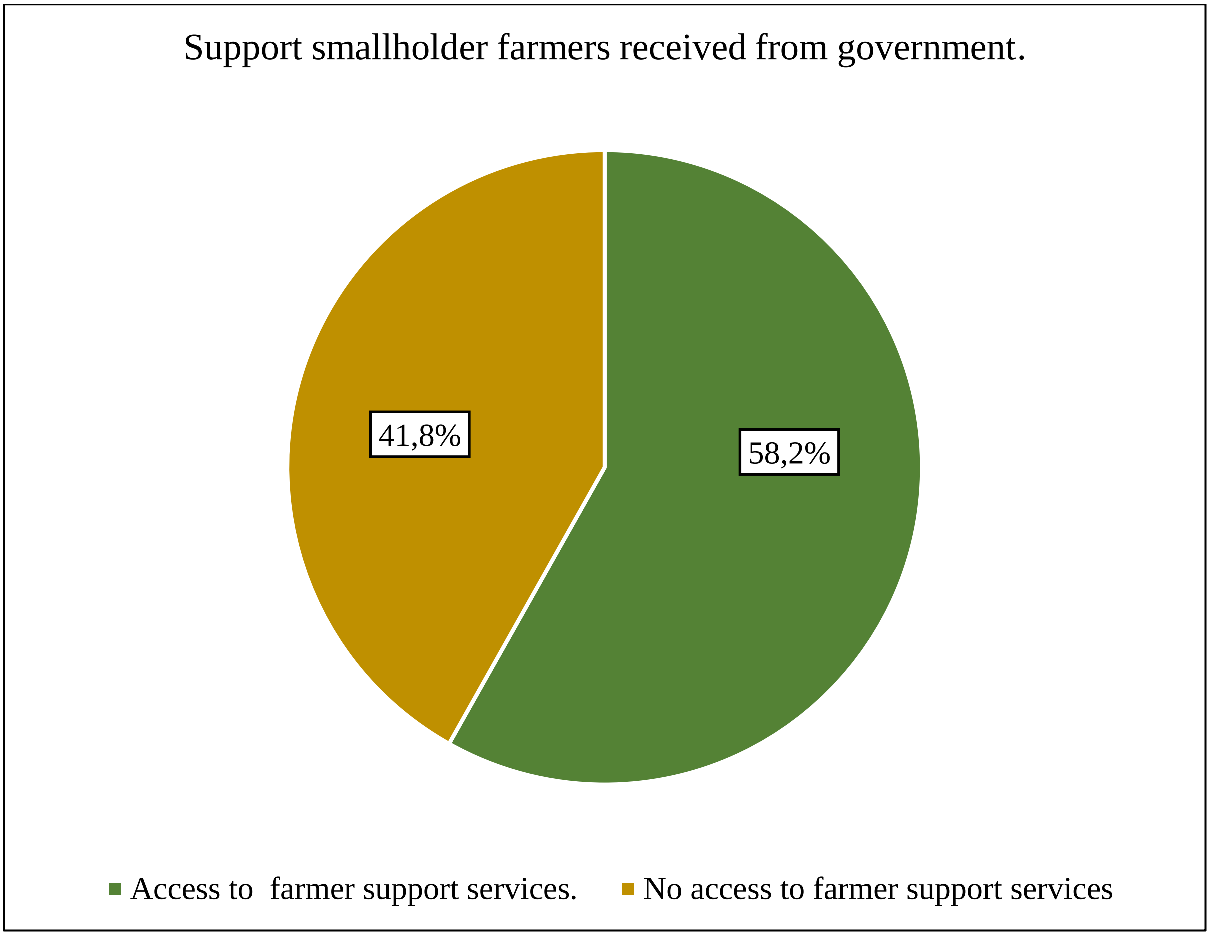



Figure 19: Support smallholder farmers received from government.
Source: Own survey, 2023.

Extension agents are liable for raising awareness on inventions, knowledge, and equipment in existence to aid in resolving the difficulties faced by farmers (Takahashi *et al.*, 2020). This denotes that smallholder farmers receive information, skills, technical advice, and motivation through engagement in agricultural extension activities as per the study findings. Also, the key task of extension specialists is to connect farmers and consumers of novel agricultural technology with the technology's creators or researchers (Mapiye *et al.*, 2021).

**6.1.11. Smallholder farmers' distribution by involvement in off-farm activities.**

Smallholder farmers' distribution by involvement in off-farm activities is presented in table 6. A substantial proportion of farmers, specifically 27.0%, receive pensions. Following this, 24.1% of farmers are involved in off-farming businesses. Additionally, 14% of farmers are not fully dedicated to farm-related activities due to alternative employment commitments. Furthermore, 15.6% of farmers solely rely on income generated from farming activities, without any supplementary streams of income. Moreover, 18.4% of farmers receive grants, primarily for childcare or disability support. Importantly, a significant portion of farmers participate in off-farm activities to augment their earnings. This approach allows them to allocate portions of their earnings toward acquiring new farming technologies or inputs, potentially improving overall agricultural practices.

**Table 5: Distribution of smallholder farmers based on engagement in off-farm activities.**

| | **Frequency** | **Percentage.** |
|---|---|---|
| Employed. | 21 | 14, 9 |
| Non-farming business. | 34 | 24, 1 |
| Social grant. | 26 | 18, 4 |
| Pension. | 38 | 27, 0 |
| No off-farm income. | 22 | 15, 6 |
| **Total.** | **141** | **100** |

Source: Own survey (2023).

A study by Setsoafia, Ma, and Renwick in 2022 has established that the adoption of innovative methods and equipment is linked to off-farm income. This relationship allows individuals in various emerging economies to overcome credit constraints they typically encounter (Osabohien, 2022). In rural areas where financial markets might be absent or dysfunctional, the utilization of off-farm income acts as a substitute for borrowed funds (Odhong' *et al.*, 2019).

The importance of off-farm income stems from its capacity to offer farmers readily available capital that can be invested in procuring productivity-enhancing resources such as improved seeds and fertilizers, as noted by Akinyi (2019). This financial resource derived from non-farm activities enables rural farmers to afford essential production inputs, including seeds, fertilizers, and renting of tractors for cultivation purposes.

### 6.2. Production systems employed by farmers and water-use efficiency practices.

The study delved into the production systems employed by smallholder farmers, focusing on their characteristics, as well as the primary source of irrigation water utilised by these farmers. Furthermore, to assess if the irrigation systems used by smallholder farmers are an outcome of the primary irrigation water source available to farmers while taking the effectiveness of the irrigation system into account. Consequently, a one-way analysis of variance (ANOVA) was employed to assess the relationship between the irrigation water source and the irrigation systems adopted by smallholder farmers.

#### 6.2.1. Description of smallholder production systems and available water sources.

From the socioeconomic features of smallholder farmers discussed in section 6.1 of this dissertation, the smallholder production systems at the study area can be characterised as female (62, 4%) dominated subsistence smallholder farms (85, 8%). The production systems are mostly 5-8 acres in size (44, 7%), and most of the smallholder farms are organic (41, 1%). Facing the issues of water availability, farmers can use alternative irrigation (87, 9%) to supplement and mitigate rainfall discrepancies.

Table 7 below presents the distribution of primary irrigation water sources available to smallholder farmers at the study area. Fifty-seven (40, 4%) of the smallholder farmers receive most of their irrigation water through the municipality supplied household water. A further 29, 1% of smallholder farmers situated near the water stream passing through the rural community, prefer sourcing irrigation water from the stream to meet their crops and livestock water needs.

Some of the water sources used by smallholder farmers at the study include a well (9, 2%), and rainwater (21, 3%).

**Table 6: Primary irrigation water source for smallholder farmers at the study area.**

| | **Frequency.** | **Percent (%).** |
|---|---|---|
| Municipal water | 57 | 40,4 |
| Rain | 30 | 21,3 |
| Water stream | 41 | 29,1 |
| Well | 13 | 9,2 |
| **Total** | **141** | **100,0** |

Source: Own survey, 2023.

The rationale behind the overwhelming preference of municipality supplied water is that it is more accessible and reliable compared to other water sources such as a water streams or wells (Tortajada, 2020). An additional reason for the use of municipal supplied water is treated to remove contaminants, making it safer to use for irrigation (Tortajada, and van Rensburg, 2020). In conclusion, the provision of water by the municipality is both cost-effective and dependable, allowing smallholder farmers to direct their attention towards other facets of their production systems. A similar result was found by Bouwer *et al.,* (2017) in a study conducted in the Western Cape province of South Africa by researchers from the University of Cape Town and the University of Fort Hare published in the journal “Water Policy” in June, 2017. The study by Bouwer *et al.* 2017, focused on the views of farmers particularly on water supply for farming purposes and found a strong preference for municipal water among smallholder farmers.

### 6.2.2. The link between irrigation water source and the use of water-use efficiency approaches.

To determine the hypothesis presented in section 5.6.1 regarding the potential impact of irrigation water source on the adoption of Water-Use Efficiency (WUE) approaches by smallholder farmers in the study area, a one-way ANOVA analysis was conducted. The results of this analysis are presented in Table 8. The study area features four main sources of irrigation water: municipal water, stream water, rainwater, and well water. As indicated in Table 8, there is no statistically significant variation observed in the correlation between irrigation water source and the adoption rate of water-use efficiency approaches, with a significance level of P>0.05 ($F_{3,137} = 1{,}808$, $P$= 0,149). The actual difference in mean scores between groups owing to these results is minimal as a statistically significant result could not be attained. Cohen (1988) categorized the effect size as small at 0, 04 using the eta squared method. According to Brydges (2019), Cohen (1988) categorizes an effect size of 0.01 as small, 0.06 as medium, and 0.14 as large. A post-hoc test was not performed as the results were not statistically significant as per Mondal *et al.*, 2022. The null hypothesis is thus accepted as the results shows that irrigation water source influences the utilisation of water-use efficiency approaches by smallholder farmers at the study area.

**Table 7: WUE approaches and irrigation water source comparison.**

| | **Sum of Squares** | **Df** | **Mean Square** | **F** | **Sig.** |
|---|---|---|---|---|---|
| Between Groups | 31,351 | 3 | 10,450 | 1,808 | 0,149 |
| Within Groups | 791,727 | 137 | 5,779 | | |
| Total | 823,078 | 140 | | | |
| Eta Squared | 0, 04 | | | | |

Source: Own survey (2023).

Based on these findings, irrigation water source determines the uptake of WUE practices at the study area. Smallholder farmers who relied mainly on surface water or ground water were more likely to cultivate crops with low water demand. Those who had adequate access to irrigation water through the municipality, rivers, and dams schedule their irrigation timeframes to limit wastage by monitoring the temperature, soil moisture and growth stage of their crops to avoid over irrigation. Liu *et al.,* (2022) corroborate these findings by asserting that various approaches can elevate agricultural water productivity. These methods include substituting water-intensive crops with those that require less water and introducing management and system modifications to enhance output per unit of water consumption. Shifting from lower-value to higher-value crops might result in a more economical and productive use of water. However, this water conservation is effective primarily when the high-value crop has a brief growth season and the land is not replanted in the same year, as outlined by Studer (2020). Efficiency must be measured in terms of the amount of redirected water which is utilized as well as the percentage that is accessible for reuse, becomes deteriorated, or is otherwise rendered useless. When the overall amount of water used by crops, evaporation, and other consumption can be decreased, efficiency increases (Liu *et al.*, 2019). By increasing efficiency to lower the wasteful water usages, the available water supply within a reservoir may also be successfully saved for additional applications and level of irrigation infrastructure.

### 6.3. Distribution of challenges among smallholder farmers in accepting formal water management systems.

Table 9 presents the distribution of challenges experienced by smallholder farmers in redesign accepting formal water management systems at the study area. The five-point Likert scale responses were analysed using the mean and standard deviation for each issue to determine the challenges farmers face when trying to modify their farming practices for water-use efficiency. Five interval ranges were developed for effective categorization of the mean obtained in the results for each issue to facilitate the results interpretation as shown in table 1 in 5.6.2. The degree of agreeing or disagreeing with statements provided during the survey data collection ranging from one to five was gauged using the mean interval ranges as depicted in table 1.

Based on the overall mean given for each challenge in table 9, the farmers agree to lacking reliable water supply (M=3,78; SD=0,85), having soils with poor water holding capacity (M=3,78; SD=0,85), absent water-efficient irrigation systems (M=3,91; SD=0,71), lack of water storage systems / facilities (M=3,85; SD=0,93), no access to credit (M=4,09; SD=0,85), inconsistent income due to unreliable markets (M=3,96; SD=0,91), insufficient knowledge on irrigation water management (M=4,00; SD=0,84), harsh and unpredictable climatic conditions as a result of climate change (M=3,89; SD=0,90).

**Table 8: Distribution of challenges faced by smallholder farmers in accepting formal water management systems.**

| Challenges. | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| I lack reliable water supply. | 141 | 1.00 | 5.00 | 3.55 | 1.02 |
| The soil on my farm has a poor water-holding capacity | 141 | 1.00 | 5.00 | 3.78 | 0.85 |
| I do not have water efficient irrigation system. | 141 | 1.00 | 5.00 | 3.91 | 0.71 |
| I cannot irrigate as much as I would due to a lack of water storage system. | 141 | 1.00 | 5.00 | 3.85 | 0.93 |
| I do not have access to credit. | 141 | 1.00 | 5.00 | 4.09 | 0.85 |

| | | | | | |
|---|---|---|---|---|---|
| My farm income is inconsistent seasonally due to unreliable market. | 141 | 1.00 | 5.00 | 3.96 | 0.91 |
| I do not have enough knowledge on irrigation water management. | 141 | 1.00 | 5.00 | 4.00 | 0.84 |
| Climate change effects such as droughts regularly affect my production output. | 141 | 1.00 | 5.00 | 3.89 | 0.90 |

Source: Own survey (2023).

The findings are consistent with the opinions of other writers about the difficulties in adopting new agricultural and technological techniques. Dessale (2020) contends that most smallholder farmers primarily depend on rainfall to fulfil their irrigation water needs. Consequently, a lack of a reliable water supply is a common contributor to low yields and food poverty. Zhou *et al.,* (2021) further states that long-term high temperatures and a protracted absence of rainfall can contribute to soil moisture deficiencies.

Smallholder farmers are at risk from the prevalent and changing climatic circumstances, such as catastrophic droughts and flooding (Mamun *et al.,* 2021). Consequently, smallholder farmers are left with insufficient water to meet their irrigation demands since irrigation infrastructures for water storage and irrigation facilities are not accessible, which results in subpar crop yields (Zerssa *et al.*, 2021). In addition to Mamun *et al*., (2021), Zhu *et al.,* (2020) state that heavy rainfall increases the likelihood of soil surface erosion and nutrient leaching. Since most fields are rain-fed (Shako *et al*., 2021), in a study conducted in Harare, Zerssa *et* *al.,* (2021) note that sorghum farmers experienced reduced yields around a decade ago due to insufficient irrigation water. Bezu (2020) asserts that failing to adapt to the changing climate might have severe implications on smallholder farming because most smallholder farms rely on rain for their irrigation demands, which may affect the smallholder farmers' capacity to earn a living. Due to the absence of legal ownership rights and solid land ownership, smallholders find it more difficult to engage in sustainable management practises, including utilising their property as collateral when attempting to obtain financing (Singirankabo and Ertsen, 2020). In a study conducted in Ethiopia, Zerssa *et al.* (2021) found that a notable barrier to the implementation of Climate-smart agriculture (CSA) practices is the deficiency of skills, encompassing inadequate knowledge.

## 6.4. The application of water-use efficiency approaches by smallholder farmers.

To evaluate the adoption of water-use efficiency approaches among smallholder farmers in the study area, the research examined the utilization of water conservation methods, the prevalence of various irrigation systems, and the types of irrigation water storage systems employed by these farmers.

### 6.4.1. Water conservation methods used by smallholder farmers.

Table 10 exhibits the distribution of water conservation methods employed by smallholder farmers in the study area. Rainwater harvesting as a water preservation method was preferred by 34,8% of respondents compared to those who use conservation agriculture (4, 3%) and mulching (4, 3%) to preserve soil moisture. The other most favoured water preservation methods are irrigation scheduling (22, 7%), and organic farming (22, 7%) with other such as dry-land farming (7, 8%), and the use of drought-resistant crops (3, 5%). The findings suggest that smallholder farmers in the study area recognize the importance of water conservation in augmenting agricultural productivity, ensuring food security, and promoting sustainable livelihoods.

**Table 9: Distribution of water conservation methods among smallholder farmers.**

| | **Frequency.** | **Percent (%).** |
|---|---|---|
| Irrigation Scheduling | 32 | 22,7 |
| Drought-resistant crops | 5 | 3,5 |
| Dry-land farming | 11 | 7,8 |
| Mulching | 6 | 4,3 |
| Conservation tillage | 6 | 4,3 |
| Organic farming | 32 | 22,7 |
| Rainwater harvesting | 49 | 34,8 |
| **Total** | **141** | **100,0** |

Source: Own survey, 2023.

Gathering and storing rainwater enables smallholder farmers to diminish their dependency on alternative water sources (wells, water streams, and municipal water), as emphasized by Shah *et al.,* (2021). Rainwater harvesting can also help replenish groundwater supplies as rainwater seeps into the ground, resulting in the recharging of ground water (Betasolo, and Smith, 2020). Organic farming practices, including the implementation of cover crops and crop rotation, play a pivotal role in enhancing soil health and minimizing water loss through evaporation, as highlighted by Franzluebbers and Martin (2022). Cover crops, such as legumes, contribute to the elevation of soil organic matter, which in turn enhances water retention capabilities (Franzluebbers and Martin, 2022). Crop rotation similarly aids in diminishing the need for irrigation by thwarting the accumulation of pests and diseases in the soil (Stark and Thornton, 2020). Moreover, adopting irrigation scheduling, which entails monitoring soil moisture levels and irrigating, when necessary, can effectively curtail the volume of water utilized for irrigation, as elucidated by Singh *et al.,* (2023). A similar study by Muchena *et al.,* (2019) demonstrated that smallholder farmers' practice of rainwater harvesting had a significant and positive effect on income and food security.

### 6.4.2. Distribution of irrigation systems used by smallholder farmers.

Figure 21 below illustrates the types of irrigation systems employed by smallholder farmers in the study area, along with their distribution across the farming community. A 44, 7% majority of the respondents prefer a manual irrigation system followed by 14, 9% of the respondents practicing rain-fed agriculture. The least favourable irrigation system at the study area is the drip irrigation system at 2, 1%. The sprinkler irrigation system (5, 0%), micro-irrigation system (9, 9%), conventional irrigation system (10, 6%), and surface irrigation system (12, 8%) are other systems of irrigation used by smallholder farmers at the study area. The application of additional irrigation by smallholder farmers can impact water use efficiency by potentially increasing crop yields but may also lead to water wastage if not managed properly (FAO, 2020). Smallholder farmers often rely on traditional irrigation methods which may not be efficient in water usage. However, adopting modern irrigation techniques and water management practices can improve water use efficiency and enhance agricultural productivity (Molden, 2007).

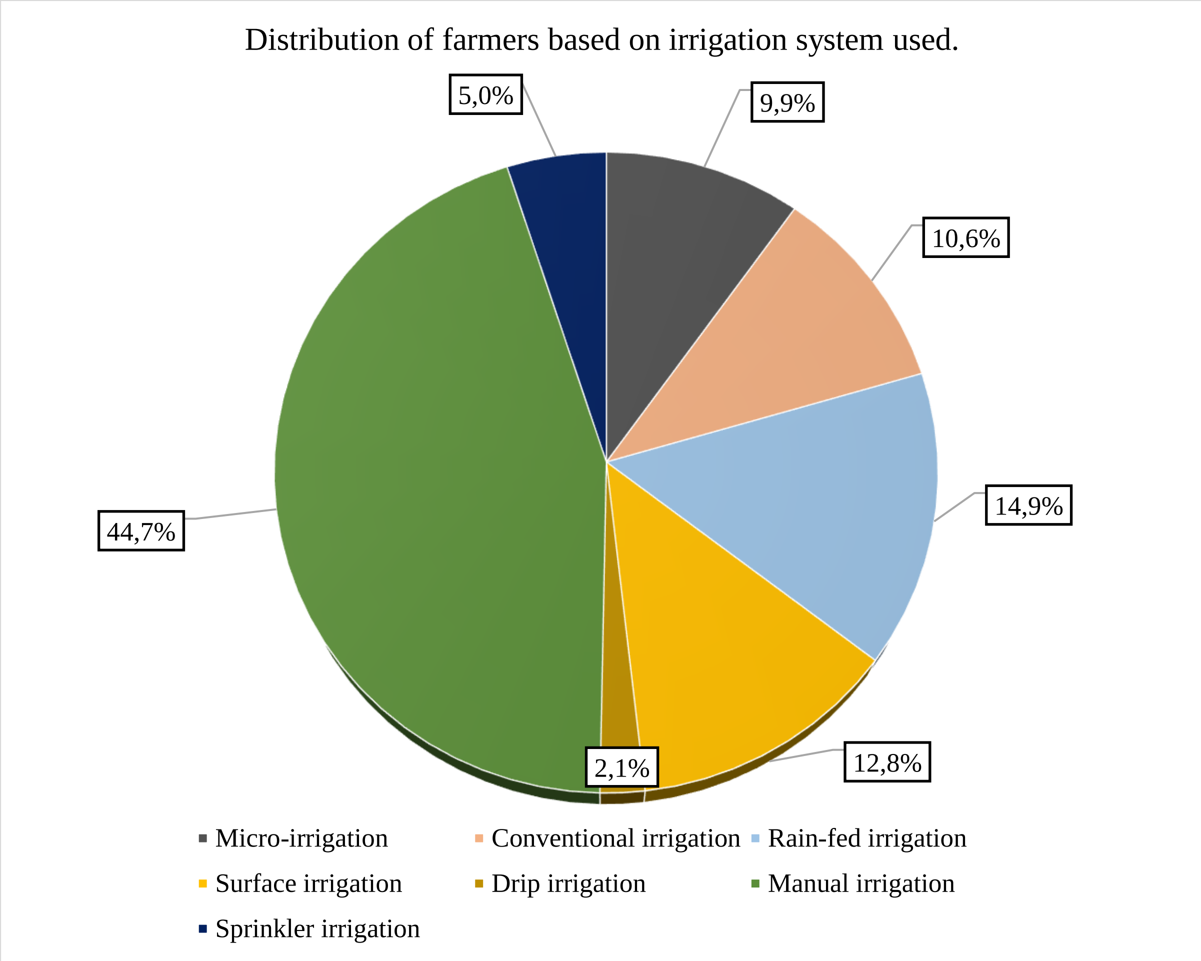



Figure 20: Distribution of irrigation systems among smallholder farmers.
Source: Own survey, 2023.

Manual irrigation systems are often more affordable and easier to maintain than the other types of irrigation systems such as sprinkler or drip irrigation systems (Beemkumar, and Ramachandran, 2023). Operational aspects of manual irrigation systems, suggest they are easy to operate and require less technical expertise as compared to other irrigation systems (Gimpel *et al.*, 2021). Manual irrigation systems allow farmers to have more control over the amount of water that is applied to their crops, which can be important in areas with limited water resources (Roy *et al.*, 2020). Lastly, manual irrigation systems can be used in a variety of environments and terrain, making them a more versatile option for smallholder farmers. Madziakapita *et al.*, (2020) found that smallholder farmers in Limpopo Province prefer the manual irrigation systems with the incorporation of buckets and watering cans, and that they were resistant to adopting new irrigation systems such as the drip irrigation systems due to the costs associated with the installation and maintenance of the irrigation system.

### 6.4.3. The water storage systems for irrigation adopted by smallholder farmers.

Figure 22 showcases the irrigation water storage systems utilized by smallholder farmers in the study area. About 40% of respondents prefer using tanks to store irrigation water collected from various sources while a small percentage of respondents rely on ground water (11, 3%). On-farm ponds (27, 0%) and soil moisture (Water absorbed and stored in the soil) at 20, 6% are some of the sources that farmers rely on as water storage systems. The findings suggest that smallholder farmers in the study area have the capacity to store water, which can be used for future irrigation requirements. This ability allows them to offset the impact of water scarcity on their crops and livestock.

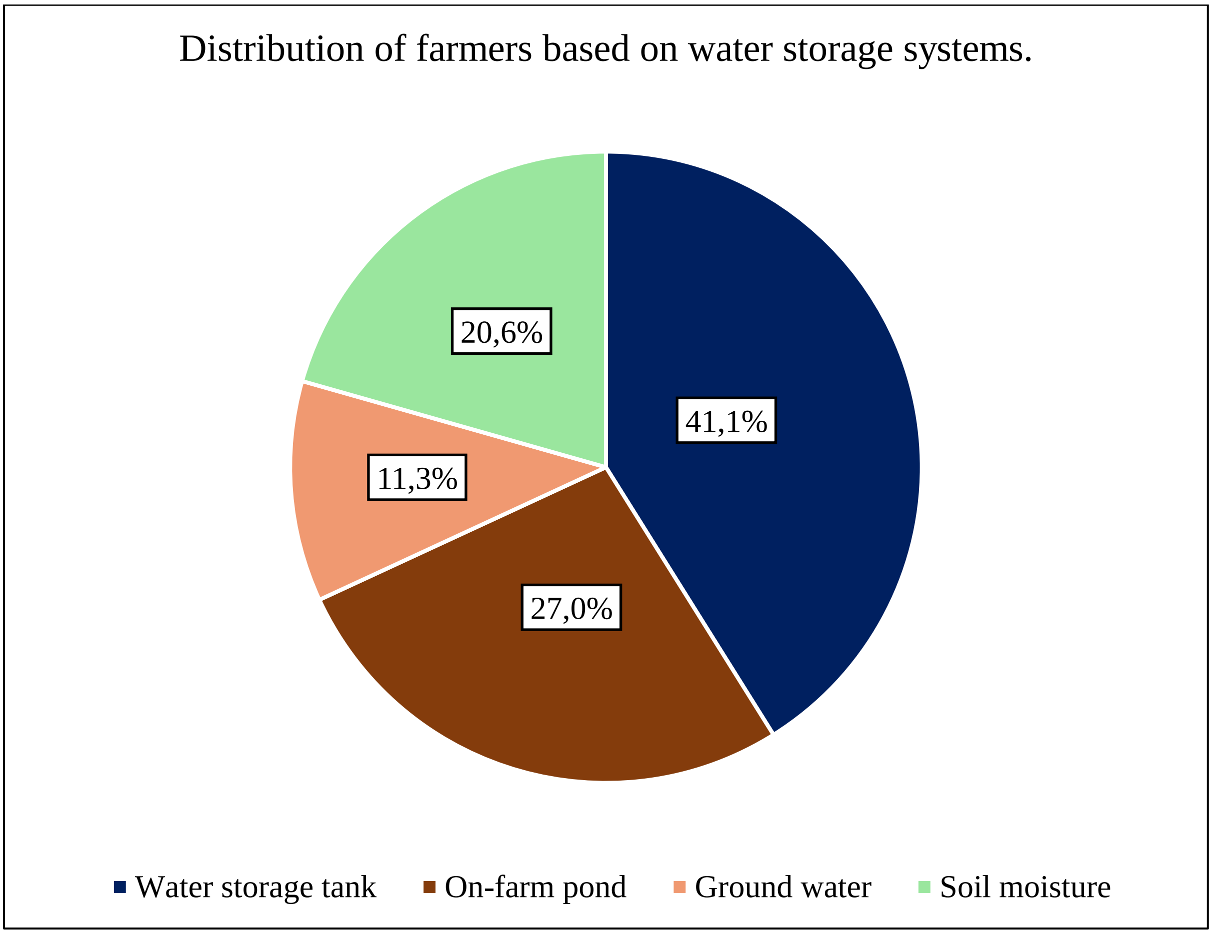



Figure 21: Distribution of farmers based on water storage systems.
Source: Own survey, 2023.

Water storage tanks are cheaper, and easier to install and maintain compared to other water storage systems such as on-farm ponds, dams, or reservoirs (Odhiambo *et al.,* 2021.) Water storage tanks can be placed closer to the crops, reducing the amount of energy and time required to transport the water. Therefore, water storage tanks can be easily adapted to a variety of sizes and can be installed on uneven or rocky terrain, which is not always possible with other water storage systems (Pili and Ncube, 2022). Ndiritu *et al.,* (2020) found that smallholder farmers in western Kenya preferred water storage tanks with a water storage capacity of 5000 litres as they were perceived to be more cost-effective and efficient compared to smaller tanks. Furthermore, the study also found that water storage tank size choices among smallholder farmers was an outcome of socioeconomic factors such as land size and household income.

### 6.4.4. Conclusion.

In conclusion, integrating water-use efficiency approaches into the practices of smallholder farmers represents a significant step towards sustainable agriculture. The study's results underscore the necessity of customized strategies tailored to the preferences and resource limitations of these farmers. Rainwater harvesting emerges as a prominent method, aligning well with local conditions and offering practical advantages. Its natural and cost-effective attributes not only enhance water availability but also reduce dependence on external sources.

The preference for manual irrigation over mechanized options highlights the practical outlook of smallholder farmers. This choice can be attributed to limited access to advanced machinery and an intimate familiarity with their land's specific demands. Opting for manual irrigation enables farmers to maintain a direct link with their fields, allowing efficient water allocation and preventing waste. Moreover, the prevalent use of tanks for storing irrigation water underscores the role of local ingenuity in water resource management. Constructed often with indigenous knowledge and locally available materials, these tanks exemplify farmers' adaptability and their capacity to harness existing resources for sustainability. These reservoirs optimize water distribution, enabling farmers to irrigate their fields even during scarcity, thereby mitigating the risk of crop loss.

# 7. CHAPTER SEVEN: THE EMPIRICAL RESULTS OF THE STUDY.

This chapter offers an in-depth analysis of the results, focusing on examining how various demographic variables of farmers, including gender, age, formal education level, and others, influence the acceptance of formal water management systems. To facilitate this investigation, the binary logistic regression model is used for analytical purposes. This chapter demonstrates the intricate relationship between independent demographic factors and the acceptance patterns of formal water management systems among smallholder farmers.

## 7.1. Acceptance of formal water management systems by smallholder farmers.

For determining if formal water management systems are accepted by farmers, the demographic characteristics (independent variable) of farmers are measured against the dependent variable (Y=Acceptance of formal water management systems) to assess if they influence the acceptance of formal water management systems. Binary logistics regression was used for this purpose. The degree to which the model can account for the variance in the dependent variable is indicated by the Cox & Snell $R^2$ and Nagelkerke $R^2$. According to the Cox & Snell $R^2$ (0, 19) and Nagelkerke $R^2$ (0, 27) for this study, this group of factors accounts for between 19% and 27% of the variability. Only results which are statistically significant are discussed below as highlighted in table 11.

### 7.1.1. Gender.

Gender is statistically significant with $P = 0, 025$ and positively influences the acceptance of formal water management systems with β = 0, 955 as presented in table 11. The likelihood that gender will affect whether formal water management techniques are accepted increases by 0, 955 when the gender in the model is increased while the other model variables are held constant. The findings are comparable to those of Musafiri *et al.,* (2022), who found that the household leader's gender had a substantial influence on the adoption of agroforestry. Musafiri *et al*., (2022) show that women were more likely than males to engage in agroforestry. The adoption of improved rice cultivars is favourably influenced by gender, according to Abdul-Rahaman *et al*.'s (2021) research. Therefore, the decision to embrace formal water management methods is heavily influenced by gender.

#### 7.1.2. Age.

Table 11 shows that age has a statistically significant *P-value* of 0, 186 and positively affects the acceptance of formal water management systems with β = 0, 260. The likelihood that age will affect whether formal water management techniques are accepted rises by 0, 260 if the variable "Age" is raised while keeping all the other factors in the model unchanged. Compared to younger farmers, an elder farmer can evaluate new technologies with more accuracy due to the information and expertise they have accumulated over the years (Chia *et al.,* 2020). Younger farmers are more prone than their older counterparts to adopt riskier practices and cutting-edge technologies (Arifullah, 2020). Research by Barnes *et al.,* (2019) indicated that age had a substantial impact on the adoption of machine guiding systems, validating the conclusions of this study.

#### 7.1.3. Educational Level.

As shown in table 11, a farmer's educational level is statistically significant with *P* = 0, 087 and β = 0, 397, indicating that education has a positive effect on whether formal water management systems are accepted. The implication of this result is that the increasing educational level while holding all other model variables constant, there is a 0, 397 percent chance that formal water management techniques will be accepted. When attempting to investigate the trends in the adoption of climate change strategies among smallholder farmers, Thinda *et al*. (2020) found that the educational level had a favourable impact on the adoption of these tactics. According to Abid *et al.,* (2019), educated farmers are often more aware of climate change and the effects of climate change on farming. Kangogo *et al.,* (2020) suggested that education improves farmers' skills and the assimilation of knowledge while enhancing the rate of innovation and technology adoption.

### 7.1.4. Farm size.

The acceptability of formal water management systems is positively influenced by farm size as highlighted in table 11, with β = 0, 373 and a statistically significant *P* = 0, 151. The likelihood that farm size will affect whether formal water management schemes are accepted is 0, 373, provided that other model variables remain constant. The use of technology is being accelerated by farmers with larger farms since they have more financial resources and available land area (Ayenew *et al.,* 2020). Moreover, they can purchase more advanced and cutting-edge technology and are risk-tolerant if the technology malfunctions. Farm size positively and significantly correlates with adoption, according to research by Darkwah *et al.,* (2019) assessing sustainable soil and water conservation methods. According to Bello *et al.,* (2021), the size of the farm has a considerable beneficial impact on the adoption of improved rice varieties in Nigeria.

### 7.1.5. Household size.

As tabulated in table 11, household size is statistically significant with *P* = 0, 041 and has a negative impact on the farmers' decision to accept formal water management systems with β = -0, 492. When household size as a parameter is increased whilst maintaining the other factors of the model used at a constant, the probability of household size being an influential factor for the farmers' decision to accept formal water management systems decreases by -0, 492. These results are in line with those of Agholor and Sithole (2020), who examined the socioeconomic traits of farmers and showed that household size had a negative impact on the adoption of modern weed management techniques by farmers. This is probably a result of low household income, which leaves little money for investments in the farm (Coulibaly, and Li, 2020).

### 7.1.6. Alternative irrigation.

The use of alternative irrigation by smallholder farmers as presented in table 11, is statistically significant with *P* = <0,001 and shows a positively influence on the acceptance of formal water management systems at the study area with β = 2, 313. An increase in alternative irrigation whilst all other variables remain constant, demonstrates a 2, 313 increase in the probability of farmers accepting formal water management systems. Irrigation is promoted because it may lower the risk involved in crop production, which leads to increased input utilization, greater agricultural yields, enhanced crop output, and crop variety (Assefa *et al.*, 2021). Therefore, there is a likelihood that farmers' incomes will increase owing to the increase in marketable surplus and commercial activity (Owusu, and İşcan, 2021).

**Table 10: The acceptance of formal water management systems by smallholder farmers.**

| | **β.** | **S.E.** | **Wald** | **df** | **Sig (*P*).** | **Exp(β)** | **95% C.I.for EXP(β)** | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Lower** | **Upper** |
| Gender | .955 | .427 | 5.001 | 1 | .025** | 2.598 | 1.125 | 5.999 |
| Age | .260 | .196 | 1.751 | 1 | .186* | 1.296 | .883 | 1.905 |
| Educational level | .397 | .232 | 2.933 | 1 | .087* | 1.487 | .944 | 2.342 |
| Farming experience | -.171 | .220 | .606 | 1 | .436 | .843 | .548 | 1.296 |
| Farm size | .373 | .260 | 2.064 | 1 | .151* | 1.452 | .873 | 2.416 |
| Household size | -.492 | .241 | 4.159 | 1 | .041** | .611 | .381 | .981 |
| Farming methods. | -.077 | .149 | .269 | 1 | .604 | .926 | .692 | 1.239 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Subsistence farming practice. | -.727 | .667 | 1.187 | 1 | .276 | .484 | .131 | 1.787 |
| Alternative irrigation. | 2.313 | .662 | 12.201 | 1 | <,001** | 10.105 | 2.760 | 37.001 |
| Farmer support services. | .087 | .411 | .045 | 1 | .832 | 1.091 | .488 | 2.442 |
| Off-farm activities | .051 | .176 | .083 | 1 | .773 | 1.052 | .745 | 1.486 |
| Constant | -4.505 | 1.358 | 11.009 | 1 | <,001 | .011 | | |
| *Statistical significance level: 0, 05 (**) and 0, 1 (*).* | | | | | | | | |

Source: Own survey (2023).

### 7.1.7. Conclusion.

In conclusion, the acceptance of formal water management systems at the study area is largely influenced by the farmers' gender, age, educational level, farm size, household size, and the use of alternative irrigation. However, even though household size is a significant socioeconomic factor in predicting the acceptance of formal water management systems at the study, it is negatively associated with the acceptance of formal water management systems.

# 8. CHAPTER EIGHT: SUMMARY, CONCLUSION, AND POLICY IMPLICATION.

## 8.1. Summary of findings.

The research aimed to address the primary objective of assessing the determinants of farmers acceptance of formal water management among smallholder farmers. The study focused on examining existing production systems for WUE, identifying constraints related to redesigning these systems, assessing the application of WUE approaches, and investigating the acceptance of formal water management systems by smallholder farmers. The study's findings reveal important traits of smallholder farmers in the research area. Most of these farmers are women, and they mainly run subsistence farms that cover 5-8 acres. A significant number of them practice use animal manure to fertilise their farms. To address water scarcity, a large portion of these farmers turn to alternative irrigation methods to mitigate the negative impacts of irregular rainfall on their production systems. This summary provides insight into the socioeconomic setting and the resourceful approaches adopted by smallholder farmers in the studied area.

The influence of the irrigation water source on the integration of water-use efficiency approaches among smallholder farmers within the study area underscores the pivotal role that water management plays in shaping agricultural practices. As the study reflect on the imperative of redesigning production systems for enhanced water-use efficiency, the profound impact of irrigation water sources becomes evident. The choice of water source emerges as a central determinant in the farmers' ability and willingness to embrace innovative strategies that optimise water consumption and safeguard its sustainable availability.

The study highlighted several challenges hindering the full transition of farmers towards water-efficient production systems, as well as their adaptability to changing climate conditions. These challenges included unreliable water supply, poor water-holding capacity of soils, lack of efficient irrigation and water storage systems, limited access to credit, fluctuating farm income and market conditions, the impact of climate change, and inadequate knowledge regarding irrigation water management.

To add, the findings of this study emphasize the significance of context-sensitive approaches to enhance water-use efficiency among smallholder farmers. By acknowledging and building upon their preferred methods, such as rainwater harvesting and manual irrigation, and leveraging their resourcefulness in using storage tanks, agricultural practices can be elevated to new levels of sustainability. However, it is essential to recognize that these practices should be supported by appropriate education, technical assistance, and infrastructure development to maximize their effectiveness and ensure long-term benefits for both the farmers and the environment.

Thus, the research highlights the strong impact of socioeconomic factors on how farmers make decisions. This is especially true for their choices regarding using formal water management systems and applying WUE approaches. In the studied area, the willingness to use formal water management services was notably affected by age, gender, farm size, household size, and education level. These factors showed a clear and important connection to how much smallholder farmers were open to using formal water management systems.

## 8.2. Conclusion.

In conclusion, this study embarked on a comprehensive exploration socioeconomic factors influencing the redesign of smallholder production systems for water-use efficiency (WUE). Through a meticulous examination of existing production systems, identification of constraints related to the acceptance of formal water management systems, evaluation of WUE approach application, and the investigation of the acceptance of formal water management systems, a profound understanding of the challenges and opportunities in this domain has been achieved.

Central to the narrative is the pivotal role of water management, specifically the choice of irrigation water source, in shaping the course of agricultural practices. The findings underscore how this choice influences the willingness and ability of smallholder farmers to embrace innovative strategies that optimise water consumption and ensure its sustainable availability. In this light, the challenges impeding a seamless transition to water-efficient production systems become evident and include unreliable water supply and poor soil water-holding capacity to financial constraints and limited access to technical knowledge.

However, within these challenges lie valuable insights into the potential pathways to sustainable agricultural practices. By integrating context-sensitive approaches and building upon farmers' preferred methods, such as rainwater harvesting and manual irrigation, it is possible to elevate agricultural practices to new heights of efficiency. Yet, this evolution must be supported by tailored education, technical guidance, and infrastructure development to maximise effectiveness and secure long-term benefits.

The study emphasises the necessity of collaborative efforts between agricultural experts, policymakers, and local communities. These collaborations will be instrumental in fostering the widespread adoption of water-use efficiency approaches, thereby enhancing resilience in the face of evolving climatic and agricultural dynamics. The research not only highlights the link between socioeconomic factors and farmers' decisions but also underscores their influence on the acceptance of formal water management services and the application of WUE approaches. Notably, factors such as age, gender, farm size, household size, and education level emerge as influential determinants of smallholder farmers' openness to formal water management systems.

In essence, this study bridges the gap between theoretical knowledge and practical implementation by shedding light on the complex interplay of factors that shape the trajectory of water-efficient production systems among smallholder farmers. The implications of these findings are far-reaching, underlining the significance of holistic, context-specific strategies to achieve sustainable agricultural practices in the face of mounting challenges related to water scarcity and changing climatic conditions.

### 8.2.1. Recommendations.

Based on the study findings, the following recommendations are proposed to redesigning smallholder production systems for water-use efficiency in Numbi, South Africa and other rural farming communities:

- **Capacity Building.**

Implement targeted capacity-building programs aimed at enhancing farmers' knowledge and skills related to formal water management practices. This could include training workshops, demonstrations, and knowledge-sharing platforms.

- **Financial Assistance.**

Provide financial support in the form of subsidies, loans, or grants to alleviate the economic burden on farmers and facilitate their investment in water management infrastructure.

- **Stakeholder Collaboration.**

Foster collaboration among government agencies, NGOs, agricultural associations, and local communities to create a supportive ecosystem for promoting the adoption of formal water management systems.

- **Policy Reform.**

Advocate for policy reforms that prioritize the needs of smallholder farmers and promote inclusive and sustainable water management practices. This may involve revising regulations, incentivizing adoption, and streamlining administrative procedures.

- **Awareness Campaigns.**

Launch targeted awareness campaigns to communicate the benefits of formal water management systems, address misconceptions, and build trust among farmers and stakeholders.

### 8.2.2. Policy implications.

Improving water-use efficiency in smallholder farming requires a holistic approach that addresses technological, social, and economic aspects. By considering the study findings stakeholders can support smallholder farmers in adopting water-efficient production systems and mitigating the challenges posed by water scarcity and climate variability. The following is proposed to improve the acceptance of formal water management systems:

- **Awareness and Training.**

Initiatives should be developed to increase awareness and provide training to smallholder farmers on water-efficient farming practices. This should include workshops, demonstrations, and educational programs that address the challenges and benefits of WUE approaches.

- **Technology and Infrastructure.**

Efforts should be made to improve access to water-efficient irrigation systems and storage facilities. Government and relevant stakeholders can provide support in the form of financial assistance and technical expertise to help farmers adopt these technologies.

- **Climate-Resilient Farming.**

Given the impact of climate change on water availability, promoting climate-resilient farming practices is essential. Farmers should be encouraged to diversify their crops, select drought-resistant varieties, and implement soil conservation measures.

- **Research and Extension Services.**

Continued research is needed to develop context-specific strategies to enhance water-use efficiency in smallholder farming. Extension services should be strengthened to disseminate research findings and best practices to farmers effectively.

- **Financial Support.**

Access to credit is crucial for smallholder farmers to invest in water-efficient technologies and infrastructure. Financial institutions and governments should develop tailored financial schemes to meet the specific needs of small-scale farmers.

- **Gender and Socioeconomic Considerations.**

Policymakers and stakeholders should consider the diverse socioeconomic factors that influence farmers' decision-making processes. Gender-specific approaches and support programs should be designed to ensure equitable access to resources and knowledge.

- **Farmer Cooperation.**

Promoting cooperation among farmers who share water resources can lead to more efficient water-use and reduce wastage. Collective water management strategies and community-driven initiatives should be encouraged.

- **Long-Term Planning.**

Sustainable water management requires long-term planning and policy interventions. Governments should incorporate water-use efficiency and conservation measures into their agricultural policies and development plans.

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**APPENDIX A: ENGLISH LANGUAGE EDITING CERTIFICATE.**


THE EXAMINATIONS COMMITTEE.

University of Mpumalanga

This confirms that the text of the dissertation prepared by **Mr. Mishal Trevor Morepje** (student number 201503045) entitled: **Redesigning Production Systems for Water-Use Efficiency amongst Smallholder Farmers at Numbi, South Africa** has been edited for language and grammar only. As is appropriate practice, direct quotes have not been edited and appear in the text as verbatim. Language and grammar edits have been attended to satisfactorily. References have not been edited.

Respectfully,

AA Wadee BSc (Hons; Toronto) MSc (Med; Wits), (PhD; WITS).
Director: ThornTree Coaching Facilitation and Mentoring.
*(Academic coaching and facilitation specialists)*

*September 16th, 2023.*

# APPENDIX B: PROPOSAL APPROVAL CERTIFICATE.

**UNIVERSITY OF MPUMALANGA**

**FACULTY OF AGRICULTURE AND NATURAL SCIENCES**

**Postgraduate Studies Committee**

***Certificate of Approval – Research Proposal***

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

**Student Details**

| | | |
|---|---|---|
| 1 | Student Name: | Morepje, MT |
| 2 | Student Number: | 201503045 |
| 3 | School | School of Agricultural Sciences |
| 4 | Degree Registered for: | MAgric |
| 5 | Date of First Registration: | 2022 |
| 6 | Supervisor(s): | Dr I. Agholor |

The research proposal entitled '**Redesigning production systems for water-use efficiency amongst smallholder farmers at Numbi, South Africa**' has been evaluated and approved by the Postgraduate Studies Committee of the Faculty of Agriculture and Natural Sciences.

**Chairperson:** Prof. Victor Mlambo

**Signature:**

**Date & Official Stamp:**

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

# APPENDIX C: ETHICAL CLEARANCE CERTIFICATE.

UNIVERSITY OF MPUMALANGA

Creating Opportunities

B Maoneke (PhD)

School of Computing and Mathematical Sciences

Mbombela Campus.

Dear Mishal Trevor Morepje

**Protocol Reference Number: UMP/Morepje/201503045/MAGR/2023**

**Project Title: Redesigning Production Systems for Water-Use Efficiency Amongst Smallholder Farmers at Numbi, South Africa.**

**Approval Notification**: In response to your application received on **15/07/2023**, The Research Ethics Committee: Faculty Research Ethics Committee has considered the above mentioned application and the protocol has been granted **FULL APPROVAL**.

**Any alteration/s to the approved research protocol i.e. Questionnaire/Interviews Schedule, Informed Consent form, Title of the project, Location of the study, Research Approach and methods must be reviewed and approved through the amendment/ modification prior to its implementation. In case you have further queries, please quote the above reference number.**

**PLEASE NOTE: Research data should be stored securely in the School/ division for a period of 5 years.**

**The Ethical Clearance certificate is only valid for a period of 3 years from date of issue. Thereafter, Recertification must be applied for on an annual basis.**

Wishing you the best with your study.

Yours faithfully,

……………………..

**B Maoneke (Chair)**

Cc: Faculty Research & Innovation Committee Chair: ………………………………….. Dr M Bembe

**DECLARATION OF INVESTGATOR(S)**

I/We fully understand the conditions under which I am/we are authorised to carry out the abovementioned research and guarantee to ensure compliance with these conditions. I agree to completion of a yearly progress report.

……………………………………………………………… ……………………………………………… 03/10/2023

Signature Date

**PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES**

## APPENDIX D: INFORMED CONSENT FORM.

UNIVERSITY OF MPUMALANGA

Faculty of Agriculture and Natural Sciences
School of Agriculture
Master of Agriculture in agricultural extension.

### Informed consent

A study entitled "**Redesigning Production Systems for Water-Use Efficiency Amongst Smallholder farmers at Numbi, South Africa**" is being conducted by **Mr Mishal Trevor Morepje** (Researcher) at your community (Numbi). The purpose of this study is to help smallholder production systems in rural parts of South Africa such as Numbi in transitioning to sustainable and water efficient livelihoods. A survey research questionnaire will be used to gather necessary information to achieve the mandate of the study. Therefore, your contribution will be highly appreciated and be of great benefit to the study. However, it's vital that you note the following terms and conditions of your participation:

- For keeping your participation anonymous, names, location, and any information that can be used to identify the participant will be kept private and/ unknown when compiling the final research report (dissertation) or when the study is distributed by forms of journal publication, dissertation, etc.
- Participation is voluntarily meaning you are free to decline or withdraw your involvement at any stage of the survey.
- To verify information provided by you (the participant), the researcher will be observing the farm and community physical resources such as cultivation practices, irrigation systems, crops cultivated, irrigation water source (dam, well, river, borehole, etc.).
- The information provided will be used by the researcher to draw conclusions as the study is concerned.
- No money, gifts, farm inputs, and other benefits of any kind will be given to the participant to influence his/her decision to take part in the study by the researcher.
- The study is not intended to impose any emotional, mental, and/or physical harm. Participants should withdraw should such occur.
- It is not compulsory to answer all questions related to the study.

By taking part in this study, you agree to all the terms and conditions provided above. The University of Mpumalanga does not take any responsibility for any breach of the above conditions by the researcher or participant as outlined in this document. By signing below, you agree that taking part in this study is of your own willingness.

Signature__________________________

# APPENDIX E: SURVEY QUESTIONNAIRE.

UNIVERSITY OF MPUMALANGA
Creating Opportunities

Faculty of Agriculture and Natural Sciences
School of Agriculture.
Master of Agriculture in Agricultural Extension.

**Research title:** Redesigning Production Systems for Water-use Efficiency Amongst Smallholder Farmers at Numbi, South Africa.

**Researcher's name:** Mr. Mishal Trevor Morepje. **Questionnaire Code:** ☐

This questionnaire serves as a tool to collect data for the research project focusing on Redesigning Production Systems for water-use efficiency amongst smallholder farmers at Numbi, South Africa. Participation is voluntary and should in any way feel uncomfortable about participating in this research, you are free to withdraw at any moment. Furthermore, your participation will be kept anonymous, and all information provided will be confidential. You are free to enquire about the purpose of this research project from Mr. Mishal Trevor Morepje who is the researcher.

**Instructions:**

- Only tick one option provided under each question.
- The questionnaire consists of seven (7) section, please answer each question.
- Section E is different from other sections, read the instruction under Section E carefully.



## SECTION A: Farmer Characteristics.

**1. Age.**

20-29 years ◯ 30-39 years ◯ 40-49 years ◯ 50-59 years ◯ ≥60 years ◯

**2. Gender.**

Male ◯ Female ◯

**3. Formal educational level.**

No school ◯ Primary school ◯ Secondary school ◯ post-secondary school ◯

**4. Farming experience.**

≤1 years ◯ 2-5 years ◯ 6-9 years ◯ 10-13 years ◯ ≥14 years ◯

**5. Farm size.**

≤ 1 acre ◯ 2-4 acres ◯ 5-8 acres ◯ 9-12 acres ◯ ≥13 acres ◯

**6. Off-farm activities.**

Employed ◯ Non-farm business ◯ social grant ◯ Pension ◯ None ◯

**7. Household size.**

1 ◯ 2-5 ◯ 6-8 ◯ 9 -11 ◯ ≥ 12 ◯

## SECTION B: Land and Agriculture.

**8. Are you a smallholder farmer?**

Yes ⬭ No ⬭

**9. What type of farm land are you farming on?**

Own land ⬭ Inherited land ⬭ Communal land ⬭ Leased land ⬭ Family land ⬭

**10. What type of farm labour do you have?**

Hired labour ⬭ Family labour ⬭

**11. How many farm labourers do you have?**

1 labourer ⬭ 2-4 labourers ⬭ 5-7 labourers ⬭ ≥ 8 labourers ⬭

## SECTION C: Production Systems Used by Smallholder Farmers

**12. Are you a subsistence farmer?**

Yes ⬭ No ⬭

**13. Farm type.**

Mixed farm ⬭ crop / Vegetable farm ⬭

**14. Which of the following farming methods do you use?**

Organic farming ⬭ Shifting-cultivation ⬭ Crop rotation ⬭ Intercropping ⬭

Inorganic farming

**15. Do you have a stable yield after each harvest?**

Yes ⬭ No ⬭

## SECTION D: Acceptance of Formal Water Management Systems.

**16. What is your water source?**

Municipal water ⬭ Rain ⬭ River ⬭ Well ⬭

**17. Do you irrigate your farming field?**

Yes ⬭ No ⬭

**18. Do you accept formal water management systems at your farm?**

Yes ⬭ No ⬭

**19. Which of the following water storage systems do you use?**

Water storage tank ⬭ On-farm pond ⬭ Ground water ⬭ Soil moisture ⬭

**SECTION E: Challenges of Redesigning Production Systems for Increased Agricultural Productivity.**

Rate the options to highlight the level at which each given statement from 21-28 relate to your farm challenges.

The options are: (1) Strongly disagree; (2) Rarely Disagree; (3) Disagree; (4) Agree; and (5) Strongly agree. Only tick one (1) option per statement using (**X**).

| | 1- Strongly Disagree | 2- Rarely Disagree | 3- Disagree | 4- Agree | 5- Strongly Agree |
|---|---|---|---|---|---|
| **21.** I lack reliable water supply. | | | | | |
| **22.** The soil on my farm has a poor water-holding capacity. | | | | | |
| **23.** I do not have water efficient irrigation system. | | | | | |
| **24.** I cannot irrigate as much as I would due to a lack of water storage system. | | | | | |
| **25.** I do not have access to credit. | | | | | |
| **26.** My farm income is inconsistent seasonally due to unreliable market. | | | | | |
| **27.** I do not have enough knowledge on irrigation water management. | | | | | |
| **28.** Climate change effects such as droughts regularly affect my production output. | | | | | |

**SECTION F: Application of Water-Use Efficiency Approaches by Smallholder Farmers.**

**29. Do you have enough water for irrigation?**

Yes ⬭ No ⬭

**20. Do you apply water-use efficiency approaches at your farm?**

Yes ⬭ No ⬭

**30. Which of the following water conservation practices do you make use of?**

Irrigation scheduling ⬭ Drought-resistant crops ⬭ dry land farming ⬭ Mulching ⬭

Conservation tillage ⬭ Organic farming ⬭ Rainwater harvesting ⬭

**31. Which irrigation system are you making use of?**

Micro-irrigation ⬭ Conventional irrigation ⬭ Rain-fed irrigation ⬭ Overhead irrigation ⬭

Surface irrigation ⬭ Drip irrigation ⬭ Manual irrigation ⬭ Sprinkler irrigation ⬭

**SECTION G: Farmer Support Services.**

**32. Are you aware of agricultural extension support services in your area?**

Yes ⬭ No ⬭

**33. Do you receive support from government?**

Yes ⬭ No ⬭



**34. Are you registered with the local extension practitioner?**

Yes ⬭ No ⬭

**35. How often do you receive the services?**

Weekly ⬭ Monthly ⬭ Every 6 Months ⬭ Annually ⬭ N/A ⬭