ASSESSMENT OF BARRIERS TO IMPROVED UPTAKE OF IRRIGATION WATER-EFFICIENT TECHNOLOGIES BY SMALL-SCALE FARMERS IN LIMPOPO AND MPUMALANGA PROVINCES

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Background

South Africa is a water-scarce country and this calls for water to be used efficiently. Water scarcity has far-reaching environmental consequences and by minimising wastage, the strain on water sources can be decreased. For instance, water scarcity poses significant challenges to ecosystems, industries and human life. It is acknowledged that communities that embrace water-saving practices are better equipped to weather periods of drought and environmental uncertainty. In an era where environmental concerns have taken centre stage, the importance of water conservation and efficiency cannot be overstated. The agricultural sector is the biggest user of water. Therefore, it is important to improve the efficiency of water use in this sector. Within the agricultural sector, it is particularly essential to improve the efficiency of water use within smallholder irrigation. This will require the adoption of efficient irrigation technologies. However, smallholder farmers face numerous challenges in adopting these technologies.

Scope of the study

This study was undertaken to identify barriers to the adoption of water-efficient irrigation technologies by smallholder farmers in two provinces in South Africa, namely Limpopo and Mpumalanga. The main aim of the study was to identify factors influencing the adoption of water-efficient irrigation technologies in smallholder irrigation in the two provinces. The specific objectives of the study were to:

a) assess and understand the socio-economic environment within which selected small-scale irrigation communities operate;
b) identify irrigation technologies that are used in two selected small-scale irrigation schemes;
c) identify the factors that influence the adoption of water-efficient irrigation technologies;
d) assess the role of “change agents” in the adoption of water-efficient irrigation technologies, and
e) identify possible ways of overcoming barriers to the adoption of water-efficient irrigation technologies.

Methods and Procedures

To address the objectives of the current study, a combination of focus group discussions (FGDs) and survey questionnaires were used. Data were gathered from smallholder farmers, scheme management representatives and extension advisors in Matsika and New Forest irrigation schemes. Although the focus of the study was on irrigation technologies used/adopted by smallholder irrigation farmers, it was decided to include crop production technologies due to their role in water use efficiency.

Focus group discussions and individual face-to-face interviews were conducted with 104 respondents in the two irrigation schemes. These data collection tools were complemented by transect walks. The data collection process started with site visits in April 2021, followed by inception meetings in August 2021 and detailed data collection during November and December 2022.

The two irrigation schemes were selected based on their perceived performance and other criteria. Matsika was classified as a good-performing scheme while New Forest was considered a poor-performing scheme. The irrigation systems used in New Forest and Matsika are flood and micro-jet, respectively. The total population of farmers in the two irrigation schemes was 114. Given the small population of farmers, it was decided to interview all of them. However, the sample included 104 farmers due to the unavailability of some of the farmers. This is 91% of the total population of farmers, who formed part of the study.

Results of the Study

The results of the study are described below:

Socio-economic environment

Poor infrastructure and lack of quality education are serious problems in the two district municipalities of Vhembe and Ehlanzeni where the two irrigation schemes are located. For instance, in Vhembe District Municipality most of the rural schools do not meet the norms and standards of educational infrastructure. Ehlanzeni District Municipality also suffers the same fate and only less than a quarter of the population has a matric qualification. Illiteracy is, therefore, a barrier to agricultural development because it can lead to a low adoption rate of new and improved technologies. Poor infrastructure makes it difficult for farmers to transport their produce to the market and inputs to their farms.

Most of the people in the two local municipalities (Thulamela and Bushbuckridge) depend on social grants due to a lack of adequate employment opportunities. Therefore, there is potential for agriculture to make a significant contribution to livelihoods by providing employment. The existence of a younger population in both municipalities presents an opportunity to participate in economic activities, such as agricultural projects, provided they are properly skilled and have relevant experience. Both Malavuwe and New Forest villages, where the irrigation schemes are located, exhibit some level of underdevelopment, characterised by high levels of poverty and unemployment. Notwithstanding the various developmental projects that have been implemented in these villages, there is room for improvement, especially in terms of permanent and sustainable employment creation.

Adoption of efficient irrigation technologies and factors affecting adoption

At least 67% of the farmers in the two irrigation schemes are using improved seeds, drought-tolerant seed varieties, and chemical fertilisers. Regarding irrigation technologies, only 29% of the farmers in the two schemes are familiar with all four types of irrigation systems (i.e. flood, drip, micro and sprinkler). In terms of irrigation water efficiency, drip irrigation was considered the most efficient by 49% of the farmers. About 12% of the farmers considered flood irrigation as the most efficient while 28% of the farmers believed that sprinkler irrigation was the most efficient. Only 5% of the farmers rated micro irrigation as the most efficient. At least 86% of the farmers indicated that they were practising irrigation scheduling.

A significant proportion of the farmers in New Forest (60%) and Matsika (32%) irrigation schemes indicated that they would like the existing irrigation system to be replaced with a more efficient irrigation one. However, they are unable to replace the existing irrigation system due to limited resources. This was particularly true for farmers in New Forest, which uses flood irrigation. About 77% of the farmers in the two irrigation schemes stated that maintenance of the irrigation system was undertaken only when needed. This is concerning as irrigation systems require regular maintenance to operate optimally.

Regarding crop production practices/technologies, only about 26% of the farmers in the two irrigation schemes do not practise conservation tillage. These farmers prefer to use traditional cultivation methods as they find conservation tillage time-consuming and costly, among other reasons. Although most farmers in the two irrigation schemes use mulching to conserve soil moisture, and improve soil fertility and plant health, some of the farmers do not. These farmers mentioned a lack of information, satisfaction with the current cultivation practice and that soil mulching was time-consuming as the reasons for not using mulching. On average, about 35% of the farmers do not practise water harvesting as they do not think it is necessary. Drought-tolerant seeds are widely used in the two irrigation schemes and about 20% of the farmers who did not use these seeds mentioned high cost and a lack of information as the reasons. Regarding irrigation scheduling, only about 7% of the farmers did not practise it as they did not think it was important. Finally, the two irrigation schemes operate in an environment characterised by poor infrastructure, high levels of unemployment, low levels of education and poor access to markets. All these affect the adoption of water-efficient irrigation technologies negatively.

Role of change agents

The majority of farmers had access to extension services in both irrigation schemes at varying levels. The primary sources for extension and advisory services were government officials at the local municipality level. Farmers in both irrigation schemes (New Forest = 78.3% and Matsika = 47.7%) indicated that they were innovators (i.e. they try out innovations and agricultural technologies as soon as they learn about them). At New Forest, about 42% of farmers identified limited access to information as a major inhibitor to adopting new irrigation technologies, despite having access to extension services. At Matsika, 43% of the farmers were categorised as late adopters of irrigation technology, and this often contributes to slow progress and growth at the farm level.

There is little indication from the farmers that they were trained on specific irrigation technologies that help reduce water wastage or related subjects such as climate change. All these factors have contributed to the little progress made by farmers in adopting water-efficient irrigation technologies in both irrigation schemes.

Conclusion

The following conclusions may be derived from the results of the study:

- The socio-economic environment within which smallholder irrigation farmers operate has limited the adoption of water-efficient technologies in the two irrigation schemes.
- Lack of resources and information are major factors limiting the adoption of water-efficient technologies among small-scale irrigation farmers.
- Extension officials have insufficiently carried out their role of transferring and training farmers on water-efficient irrigation technologies. The focus of extension services has been on general farming activities (primary production and marketing of agricultural products) and information transfer. There is limited attention to the training of farmers on improved technologies, including water-efficient irrigation technologies.

Recommendations

Based on the findings of this study, the following recommendations are made to improve the uptake of efficient irrigation technologies:

- Implementation of measures that will provide information about water-efficient technologies and the benefits that can be derived from adopting them is essential.
- The information on water-efficient technologies should at least cover site-specific applications of fertiliser, drought-tolerant seeds, mulching, no-tillage cultivation, water harvesting, and irrigation scheduling.
- Methods that have proved effective in providing information on technology adoption to farmers should be considered for implementation in the two irrigation schemes. These include farmer training (by extension agents), social learning (farmer-to-farmer exchange of information) and the establishment of demonstration plots in providing information to farmers about new technologies.
- Farmer training provided by extension officers should place more emphasis on water-efficient technologies. The training should include creating awareness about the importance of using irrigation water efficiently and the various technologies that can be used to achieve this.
- External financial assistance should be provided to the farmers to facilitate the adoption of water-efficient technologies, which can be quite costly. In the case of inputs such as chemical fertilisers and drought-tolerant seeds, the assistance can take the form of government subsidies and/or low-interest credit. However, in cases where smallholder farmers wish to switch from the existing irrigation system (e.g. flood/gravity irrigation) to a more water-efficient system (e.g. sprinkler, micro or drip irrigation), government grants or donations from the private sector or NGOs may be the most effective form of financial assistance.
- Government should play a crucial role in addressing issues of physical infrastructure such as roads and market facilities. The irrigation infrastructure at New Forest is damaged in many places, resulting in major water losses. Unless these facilities are repaired, water losses will continue and any measures to improve water efficiency by adopting efficient technologies will be futile. Government will have to step in to repair the irrigation infrastructure as the repair

cost is too high for the farmers. Farmers themselves will need to implement measures to safeguard the infrastructure once it has been repaired.

- Measures to improve access to input and output markets should be implemented as farmers in the two irrigation schemes operate in an environment where access to markets is poor. Ensuring that farmers' cooperatives function well can be an effective way of improving access to markets.
- Farmers should be incentivised to use irrigation water efficiently. It has been shown elsewhere that requiring farmers to pay for irrigation water increases the value of the water. This is something that needs to be explored at Matsika and New Forest to determine if such incentives are appropriate and can lead to improved water efficiency.
- Data on weather patterns, water availability, and soil moisture levels, to mention a few, should be provided to the farmers so that they can practise irrigation scheduling. It should also be established whether real irrigation scheduling can be implemented given the way irrigation plots in the irrigation schemes are arranged.
- Measures should be taken to improve working relations between the farmers and government officials, especially at Matsika. Ideally, this should involve a third party as farmers and government officials are unlikely to resolve the existing conflict themselves.
- Training should be provided to the farmers to equip them with skills that can assist in conflict resolution and efficient management of the irrigation schemes. These skills may include communication, conflict resolution, and teamwork, to mention a few, that can be imparted through adult education.
- The formation of farmer cooperatives (or their strengthening where they already exist) should be promoted to manage irrigation schemes, invest in irrigation infrastructure, and provide inputs and marketing services for the farmers.
- The management of the Matsika irrigation scheme should be restructured to ensure it is representative of the farmers and acts in their interest. It is not in the best interest of the farmers for the management to be dominated by a single individual.

Future Research

The following are recommended for future research:

1. This study did not consider the issue of dis-adoption, which has become important in research on technology adoption among small-scale farmers. By not considering dis-adoption, we will not know whether those who indicated they were not using/practising efficient-irrigation technology previously used/practised these technologies. Also, those using/practising efficient-irrigation technologies could have dis-adopted some of the technologies. Future research that addresses the issue of dis-adoption will assist in gaining a better understanding of the factors influencing the adoption of water-efficient technologies.

2. The study was largely qualitative due to data limitations. Future studies that are more quantitative would generate more revealing findings.

3. The current study considered the various water-efficient technologies but did not go deeper into each one of them to gain more understanding of what may affect their adoption. A more detailed analysis of the factors affecting the adoption of each specific water-efficient technology could yield better results.

4. Future research should consider the extent to which the training provided by extension officers and others has been adopted and applied.

5. Assessing the impact of adopting water-efficient technologies on water use efficiency and agricultural production in smallholder irrigation would be useful to consider in future research.

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APAP	Agricultural Policy Action Plan
ARC	Agricultural Research Council
ARD	Agricultural Research for Development
BLM	Bushbuckridge Local Municipality
CIRAD	French Agricultural Research Centre for International Development
CV	Contingent Evaluation
DAFF	Department of Agriculture, Forestry and Fisheries
DOI	Diffusion of Innovation
DWS	Department of Water and Sanitation
EDM	Ehlanzeni District Municipality
EI	Economic Instrument
EPWP	Expanded Public Works Programme
FAO	Food and Agriculture Organisation
FGDs	Focus Group Discussions
GEAR	Growth, Employment and Redistribution Policy
GHS	General Household Survey
IDP	Integrated Development Plan
IMT	Irrigation Management Transfer
MENA	Middle East and North Africa
NGOs	Non-Governmental Organisations
NPC	National Planning Commission
NPV	Net Present Value
NWRS	National Water Resource Strategy
PTO	Permission to Occupy
RDP	Reconstruction and Development Programme
RESIS	Revitalisation of Smallholder Irrigation Schemes
SAII	South African Irrigation Institute
SSIs	Semi-Structured Interviews

TLM	Thulamela Local Municipality
VDM	Vhembe District Municipality
WANA	West Asia and North Africa
WRC	Water Research Commission
WTP	Willingness to Pay
WUE	Water Use Efficiency

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CHAPTER 1: INTRODUCTION

1.1 Background

Given that South Africa is a water-scarce country, it is important to ensure water is used efficiently. Water scarcity has far-reaching environmental and socio-economic consequences and by minimising wastage, the strain on water sources can be decreased. For instance, water scarcity poses significant challenges to ecosystems, industries, and human life. According to the Department of Water and Sanitation (DWS), irrigation accounts for about 65% of water use in South Africa (DWS, 2016). Improving the efficiency of water use in the agricultural sector will be crucial as it is the biggest user of water. It is, therefore, critical that irrigation water use and productivity of existing irrigated land in the country should increase to address future food requirements of a growing population. Within the agricultural sector, it is important to increase the efficiency of water use in smallholder irrigation as it has been shown that the efficiency of water use in this subsector can be improved. For example, Machethe et al. (2004) found that smallholder farmers applied excessive amounts of water when it was their turn to irrigate their plots. Thus, improving water use efficiency (WUE) can contribute to water saving and food security, particularly if this can be achieved without land expansion (Jarmain et al., 2014).
Improving the efficiency of water use in smallholder irrigation requires the adoption of irrigation-efficient technologies. These include efficient irrigation systems and crop production practices. Irrigation systems considered to be water-efficient include drip, sprinkler, and micro irrigation. Flood irrigation, which is used in many smallholders' irrigation schemes, is considered to be less efficient in water use. Crop production practices that can enhance the efficiency of water use include drought-resistant crop varieties, mulching, conservation tillage, irrigation scheduling, and water-harvesting irrigation. The choice of irrigation technology affects water use efficiency. For example, the adoption of drip irrigation increases water use efficiency (Garb and Friedlander, 2014; Bijay et al., 2018).

While it is generally accepted that the adoption of water-efficient irrigation technologies can contribute significantly to water saving, smallholder farmers often experience barriers in the adoption of these technologies. Smallholder irrigators lack effective means of production and mostly rely on manual methods. Furthermore, incomes from irrigation are relatively low and severely constrained by the small fields and high operating costs (Torou et al., 2013). Poor service delivery and weak performance in the management of water services by municipalities exacerbate the myriad irrigation challenges facing smallholder farmers.

Taken together, these constraints put at risk the attainment of water security, which is defined by the United Nations as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (DWS, 2016). Matthews (2019) noted that accelerating technological development and implementation of innovation are the linchpin to progress towards global water security, climate adaptation, and sustainable growth. Without enhancing water security, countries will be unable to adapt, decarbonise, or be resilient to climate change and other shocks and stresses. This is particularly true for rural communities. It is also acknowledged that communities that embrace water-saving practices are better equipped to weather periods of drought and environmental uncertainty. In an era where environmental concerns have taken centre stage, the importance of water conservation and efficiency cannot be overstated. Challenges of water management are increasingly getting acute considering climate change, which has resulted in more frequent and intense droughts or floods, growing water demand for industrial and agricultural use, and water pollution (Fanadzo and Ncube, 2018).

1.2 Research Problem

According to Masere (2015), over the past five decades, the development of improved agricultural technologies, and the eventual adoption of these technologies by farmers, have led to extensive changes in agriculture. The adoption of yield-increasing and labour-saving technologies has enabled farmers to increase yields, expand operations, and increase efficiency ratios. Modern technology in agriculture also has reduced the need for human labour and resulted in farm production becoming increasingly concentrated on fewer farms. Ayenew et al. (2020) and Mendola (2007) reiterated that the adoption of improved technologies has a positive and significant effect on the welfare of households. This is because technology adoption contributes to improving food security and increases the incomes of the adopters (Kopalo et al., 2021; Teka and Lee, 2020).

Despite the importance of improved technologies in transforming the agricultural sector and improving the welfare of smallholder farmers, the level of adoption among smallholder farmers remains low in South Africa. The government has made efforts to increase the level of technology adoption among smallholder farmers through measures such as establishing irrigation schemes and providing input subsidies. The low adoption of new technology may be due to numerous factors such as poor extension services, a lack of capital and the exclusion of farmers in the decision-making process (DAFF, 2010). High initial capital requirements of water-efficient technologies may contribute to widening the gap between smallholder farmers and large-scale farmers as the latter are more likely to adopt these technologies due to their access to investment capital (DAFF, 2010).

Smallholder farmers often do not have the resources and inputs that are necessary for optimal production. Hence, support to these farmers needs to be structured in such a way that they get the much-needed assistance to continue producing under climate-change conditions (Kephe et al., 2021). In addition, negative perceptions of water-efficient technologies may prevent their adoption by smallholder farmers. Bonsta et al. (2023) posited that socio-psychological factors such as trust, and openness, in combination with demographic factors such as age, gender, and level of education contribute to poor technology adoption. Caffaro et al. (2020) noted that perceptions towards digital technologies relate to usefulness, increased productivity, cost reduction, efficiency, and workload reduction.

Although much is known about the reasons why smallholder farmers do not adopt technologies, information on why smallholder irrigators have not adopted efficient irrigation technologies remains scanty. Therefore, research is needed to identify barriers to the adoption of efficient irrigation technologies. This can potentially provide information on what needs to be done to improve the uptake of efficient irrigation technologies.

1.3 Research Objectives

The main aim of the research was to identify the factors influencing the adoption of water-efficient irrigation technologies in smallholder irrigation schemes in Limpopo and Mpumalanga provinces. The specific aims of the study were as follows:

a) To assess and understand the socio-economic environment within which selected small-scale irrigation communities operate.
b) To identify irrigation technologies that are used in two selected small-scale irrigation schemes.
c) To identify the factors that influence the adoption of water-efficient irrigation technologies.
d) To assess the role of "agents of change" in the adoption of water-efficient irrigation technologies.
e) To identify possible ways of overcoming barriers to the adoption of water-efficient irrigation technologies.

1.4 Structure of the Report

This report is divided into eight chapters. Chapter 1 provides the background of this study, and presents the problem statement and rationale for this study, including the study aims and objectives. Chapter 2 is a review of the literature covering various topics, such as the global and national overview of smallholder irrigation, irrigation technologies used by farmers, the socio-economic environment shaping small-scale irrigation, and role players in smallholder irrigation. This is followed by Chapter 3, which describes the research methods and procedures employed in the study. Chapter 4 assesses the socio-economic environment within which smallholder irrigation operates. The results of the study on the adoption of water-efficient technologies are presented in Chapter 5. Chapter 6 presents the research results on factors affecting the adoption of water-efficient technologies. The results of the study on the role of change agents in the adoption of irrigation-efficient technologies are presented in Chapter 7. The summary of the study, conclusions and recommendations for removing barriers to the adoption of efficient irrigation technologies are presented in Chapter 8.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on smallholder irrigation and is organised as follows: Section 2.2 provides an overview of smallholder irrigation globally, covering the nature and importance of smallholder irrigation, role players in smallholder irrigation, the socio-economic environment within which smallholder irrigation operates, irrigation technologies used within smallholder farming and why smallholder farmers need to adopt new technology. This is followed by an overview of smallholder irrigation in South Africa in Section 2.3, covering the origin and evolution of smallholder irrigation in the country, role players within irrigation, size of the small-scale irrigation, and irrigation technologies used within smallholder farming. Section 2.4 reviews the literature on water use efficiency in the context of smallholder irrigation. A literature review on the process of technology adoption in the context of both smallholder agricultural development and smallholder irrigation is presented in Section 2.5. This section includes the determinants of technology adoption in small-scale agriculture, the process of technology adoption and the role of change agents in the adoption of irrigation-efficient technologies. Section 2.6 provides a summary of the chapter.

2.2 Small-scale Irrigation: Global Overview

2.2.1 Description of small-scale irrigation

The terms “small-scale irrigation” and “smallholder irrigation” are used interchangeably in this document to refer to irrigation arrangements involving smallholder or small-scale farmers. This type of irrigation entails agricultural projects in which several smallholder farmers cultivate crops, relying on a common source of irrigation water, with each farmer operating on his/her piece of land. In South Africa, these projects are referred to as irrigation schemes.

Otsuka and Larson (2012) defined an irrigation scheme as a multiple-holding project, which is dependent on a shared system of distribution to access water. Backeberg and Groenewald (1995) defined an irrigation scheme as a multitude of entities sharing irrigation water from one bulk water system. In South Africa, these irrigation schemes were established by the state and designed to enhance food production and provide relief during periods of drought, while providing employment opportunities, particularly in the rural sector (Irajpoor et al., 2011). Shah et al. (2002) observed that, in Africa, small-scale irrigation schemes were designed with small-scale user groups in mind and, therefore, they were designed as large-scale, single-unit systems with no flexibility to accommodate individual small-scale operations.

Global experience with irrigation practices has revealed that small-scale irrigation systems are easier to design and manage. This is different from the large-scale irrigation systems, which are mainly used by commercial producers. The centre-pivot type of irrigation technology is usually preferred by large-scale producers as it covers a wide range of cultivated land (Burney and

Naylor, 2012). The utilisation of large-scale irrigation systems has been found to have more challenges than small-scale irrigation. Large public irrigation systems need to be modernised because, in some cases, they lead to low agricultural productivity. Although there are differences between small-scale and large-scale irrigation, both require support (Burney and Naylor, 2012).

2.2.2 Importance of small-scale irrigation

Smallholder irrigation can be an effective way to deal with challenges associated with climate change. Climate change presents challenges for smallholder farmers in the form of drought and floods, which lead to lower yields, income, and food insecurity. Small-scale irrigation can have a positive impact on rural livelihoods. Income generation, poverty reduction, and increased crop yields are some of the benefits derived from small-scale irrigation. Small-scale irrigation systems/technologies also lead to knowledge generation for small-scale producers (Lipton et al., 2003; Hussain et al., 2003; Hussain and Hanjra, 2004).

In South Africa, small-scale irrigation has the potential to increase food production, thus, contributing to the Agricultural Policy Action Plan (APAP), which is guided by the 2030 vision statement of the National Development Plan and the New Growth Path. The National Development Plan Vision 2030 (NPC, 2011) stated that one million new jobs can be created in agriculture over the next few decades, mostly labour-intensive forms of small-scale farming in communal areas and on redistributed land, with many engaging in irrigation farming. Although the NDP indicated that irrigation can be expanded by 500 000 hectares, the Department of Water Affairs (DWA) in the National Water Resource Strategy (NWRS) indicated that there is only water available for 80 000-hectare expansion. The Department of Agriculture, Forestry and Fisheries (DAFF) in 2018 indicated that only 35 000 hectares can be further developed at a cost of approximately R200 000 per hectare. The misalignment amongst NDP, DWA in the NWRS and DAFF regarding the available water for potential expansion of areas under irrigation may have a bearing on some of the challenges faced regarding further development of irrigation schemes in South Africa.

2.2.3 Role players in small-scale irrigation

According to Mwadzingeni et al. (2020), institutional actors in smallholder irrigation schemes include international (e.g. Food and Agriculture Organisation of the United Nations, and International Monetary Fund), national and local institutions. In their study, the following were categorised as local institution actors: government agencies, universities, irrigation committees, non-governmental organisations, traditional leaders, private sector organisations and water users’ associations (Mwadzingeni et al., 2020).

The functionality of small-scale irrigation schemes is highly dependent on the stakeholders involved. The role players in the irrigation schemes are not only limited to the small-scale producers (targeted group). Small-scale irrigation stakeholders also include those involved in planning, service providers, engineers, policy makers and other organisations who ensure the sustainability of the irrigation schemes. In addition to the targeted group (which may not be highly knowledgeable and experienced, in some instances), the small-scale irrigation scheme needs highly knowledgeable and experienced individuals. This may require some understanding and negotiation to balance these groups of individuals to work together for the success of the schemes. Continued support is, without a doubt, a necessity to ensure that the irrigation scheme attains its intended objectives (Fanadzo et al., 2010).

2.2.4 Socio-economic environment within which small-scale irrigation operates

The relationship between economic systems and social structures determines the distribution of resources, money and power in a community (Collaborative on Health and the Environment, undated). Access to education, income and power shapes access to resources. The socio-economic status of an individual is composed of his/her economic, social and work status in comparison to that of the larger community. It follows from the above that the performance of smallholder farmers and their irrigation schemes will be dependent on the socio-economic environment within which they operate.

Many small-scale producers operate in poor socio-economic environments. Problems related to water, electricity, infrastructure, and access to markets characterise the socio-economic environments in which smallholder farmers operate. Access to quality infrastructure remains a huge bottleneck to the development of the small-scale farm sector (Dutta et al., 2020). On the social side, access to education and health remains a problem for communities in which smallholder farmers reside. All these factors affect the operation of smallholder irrigation schemes, including the adoption of irrigation water-efficient technologies. Producers are not motivated to invest in costly irrigation technologies in the presence of these challenges. Smallholder irrigation requires comprehensive support which ensures that farmers have access to physical infrastructure and social capital.

2.2.5 Irrigation technologies used by small-scale farmers

In small-scale irrigation, there are different types of irrigation technologies in use. The use of these different technologies is dependent on several factors, which include finance, maintenance, knowledge, and crop type, among other factors. Small-scale technology can be categorised into modern, traditional, and low-cost technologies. These may not be mutually exclusive as some modern and traditional technologies may also be low-cost technologies. Modern irrigation technologies include drip, surface, and sprinkler irrigation. These modern systems are mostly developed to reduce energy costs and water waste (Otsuka and Larson, 2012). Irrigation technologies used in smallholder irrigation include sprinkler, drip, flood, and micro irrigation.

Sprinkler irrigation

Sprinkler irrigation is potentially less wasteful of water and uses less labour than surface irrigation. It can be adapted more easily to sandy soils subject to erosion on undulating ground, which may be costly to re-grade for surface methods. Different types of sprinkler irrigation systems are suitable for different farms. The type of sprinkler commonly used uses portable aluminium or plastic pipes. These pipes supply tiny rotary sprinklers. Although sprinkler irrigation has numerous advantages, it necessitates complex design skills as well as on-farm support regarding supply and the maintenance of additional parts (Otsuka and Larson, 2012; Scherer, 2005).

Drip irrigation

Drip irrigation is a type of modern irrigation technology, which is not yet used on a large scale. This irrigation system is commonly used in countries like Israel, and it is regarded as the most effective and efficient irrigation method. It consists of a system of emitters and pipes transporting tiny frequent irrigation to a single plant. Producers using this type of irrigation can time it and control the amount of water to be used. This irrigation system makes it easier to ensure that the crop receives its water demand while ensuring that there is no water wastage. The wastage of water takes place if there are unfixed pipe leaks. Water is also wasted when the irrigation technology is left unattended for too long. The suppliers of this system have claimed that this system has resulted in increased crop yields and saved water. These claims still require further investigation (Alcon et al., 2011). The sand, algae and chemical blockages along the emitters and pipes are the technical challenges faced when using the drip irrigation system. Many who use this type of irrigation system are still struggling to deal with the challenges faced. However, some small-scale producers can manage the challenges by ensuring that they clean the system regularly. The other disadvantage of drip irrigation is that it is costly and demands a larger amount of capital than most irrigation systems. Although this method is expensive, it has been found to have a great impact on crop yields (Van Averbeke et al., 2011).

Micro irrigation

Micro irrigation is an irrigation system that has a lower water pressure and flow than sprinkler irrigation. It is an irrigation system that applies water slowly to the roots of plants. The water can be applied directly to the root zone or the soil surface through a network of pipes, valves, tubing and emitters (Reinders, 2011). Micro irrigation is considered one of the most efficient irrigation systems. However, it is costly and may be out of reach of smallholder farmers.

Flood irrigation

A range of traditional irrigation technologies are used by smallholder farmers. These methods include swamp irrigation, spate irrigation, floodplain irrigation, water harvesting irrigation and groundwater irrigation. The traditional types of irrigation can be labour-intensive and time-consuming but remain cheaper than other methods. Traditional and modern technologies are different to low-cost technologies. Low-cost technologies are modern methods designed and reformed to reduce the cost of irrigation. The treadle pump is one of the technologies designed as a low-cost pump for small-scale producers. It is still being adopted among the local producers across Africa. The treadle pumps were designed to eliminate the lifting and carrying of water to the plants. Low-cost modern technologies can assist producers in moving from subsistence farming to small-scale producers (Walters and Groninger, 2014).

2.2.6 Importance of adopting new technology in small-scale farming

Historically, the productivity of small-scale farming systems has been plagued by numerous structural and policy issues that have led to slow increases in yields and even stagnation in some parts of the world and for some crops (Yengoh et al., 2010; Lipton et al., 2003). A lack of technology, and limited access to or the use of inappropriate technology are among the factors associated with low productivity and food deficiency in poor countries (von Braun et al., 2007; McCalla, 1999; cited in Yengoh *et al*., 2010). There is an expectation that with the right technology in place (i.e. better seeds, fertilizers, tools, techniques, and others), agricultural production will routinely be increased, and challenges of food security overcome in areas with some physical and social limitations to food production (Yengoh et al., 2010).

There is the desire to achieve improvements in productivity while facing up to the contemporary challenges of global environmental change: global warming, land degradation, water pollution and scarcity, and biodiversity loss (World Bank, 2007). To this end, new policies and programmes are put forth that, in turn, drive technological changes in developmental contexts and sectors, including the agricultural sectors. Basic technologies have been promoted over time, some of which have not yet reached many in the small-scale production sub-sectors (Yengoh et al., 2010).

International agencies, national governments, regional authorities and local concerned groups attempt at different scales to make agriculture more productive and profitable by introducing technologies to meet or reduce some of the constraints of farm production. These constraints include soil erosion, depleted soil nutrients, low quality of seeds, over-grazing, the use of rudimentary farming tools and techniques, among others (Yengoh et al., 2010 citing Ahmed, 2004). Despite modest outcomes resulting from these efforts, some small-scale farmers are characterised as early adopters of technologies for various reasons. Due to the high levels of vulnerability of small-scale farmers to productivity and production challenges, any losses incurred tend to magnify impacts on livelihoods. Furthermore, the conditionality and incentives linked to small-scale farmer support programmes often influence the adoption and diffusion of new technologies (World Bank, 2007).

2.3 Overview of Small-scale Irrigation in South Africa

2.3.1 The origin and evolution of small-scale irrigation in South Africa

Smallholder irrigation schemes were established in the former homeland areas to improve the livelihoods of smallholder farmers and their families by increasing agricultural productivity and production, thereby achieving food security and poverty alleviation (FAO in Mkeni, 2010).

Irrigation is necessary where rainfed agricultural production is not viable, which is the case in most former homeland areas.

The South African smallholder irrigation schemes are largely shaped by the government policy of racial segregation and the irrigation technology used in different eras. These included periods such as the Peasant and Mission Diversion Scheme era; the Smallholder Canal Scheme era; the Independent Homeland era, and the Irrigation Management Transfer and Revitalisation era. Peasant and Mission Diversion Scheme era was introduced during the19th century and was also noted as the first era of smallholder irrigation development in South Africa. According to Bundy (1988), this era was linked with mission activity and the development of the African peasantry. Backeberg and Groenewald (1995) mentioned that the era overlapped with the early part of the Individual Diversion Scheme era whereby irrigation development was private, and the technology used was that of river diversion, which is similar to the peasant era. During this period, the area under irrigation production was less important until the irrigation schemes that were developed ceased to function by the end of the 19th century.

The Smallholder Canal Scheme era commenced from 1930 until 1960 and was, therefore, considered as the renewed smallholder irrigation development that took the form of canal irrigation. This period coincided with the public storage schemes period (Backenberg and Groenewald, 1995). The smallholder canal schemes were mainly aimed at providing African families residing in the so-called “Bantu Areas” with a full livelihood. According to Van Averbeke and Mohamed (2006), many of the irrigation canal schemes of this period were developed on the land that belonged to the state and farmers held their plots using Permission to Occupy (PTO), thereby empowering the state to prescribe how land could be used while those farmers who did not comply with state rules were expelled and replaced. For the largest part, during this period, irrigation projects obtained water from the river and built storage dams using concrete water weir diversion and concrete canal conveyance systems. During this period, black people were allocated smaller plots of about 1.5 hectares whereas poor white settler farmers were allocated 8-20 hectares to derive full land-based livelihoods (Backeberg and Groenewald, 1995; Van Averbeke et al., 2006). This kind of allocation suggested that black families needed relatively less land and consequently less income to realise full livelihood potential as compared to white families (Backeberg and Groenewald, 1995; Van Averbeke et al., 2006). Nonetheless, during this era, the state was in control and there was no farmer involvement. Thus, these farmers were utilising the land according to state instructions and problems experienced during this period led to the establishment of the RESIS programme.

The third period of irrigation development comprised the independent homeland era and lasted from 1970 until 1990. It was regarded as an important era of the economic development of the homelands. The irrigation methods used were characterised by modernisation, functional diversification, and centralisation of scheme management. On some of the smaller schemes, pressurised overhead irrigation systems were used instead of surface irrigation. The functional diversification was used for rural homesteads and delivered diverse options to benefit from irrigated agriculture, depending on the structure and existing livelihood of the farmers. For instance, mini farms catered precisely for homesteads that sought full land-based livelihoods, and the food plots provided homesteads that derived their livelihoods from external sources such as male migration or old-age pensions with an opportunity to enhance these livelihoods by producing food for home consumption. One of the key strategies of the homeland system was to fund the development of the irrigation schemes from the South African government since agriculture was regarded as the main internal development opportunity for the homelands and their resource base continued to be essentially rural (Van Rooyen and Nene, 1996; Lahiff, 2000). Again, during the homeland period, there were also large schemes that were developed, which were complex from economic and social perspectives and were also costly to maintain. Therefore, the sustainability of these schemes was affected by the conflicts and social unrest that took place during the late 1980s. These agricultural parastatals were dismantled by the provincial governments immediately after the democratisation of South Africa in 1994. Eventually, large schemes were mostly affected, and their production collapsed due to their complexity and centralised management since their establishment (Van Averbeke et al., 1998; Laker, 2004).

The next period which characterised irrigation development in South Africa is the Irrigation Management Transfer (IMT) and revitalisation era that started around 1990 when political change in the country became inescapable. Evidently, this is the era that was guided by the epitomes of democracy and a better life for all. During this period, the aim was to eradicate poverty and improve the quality of life among black people in rural areas and informal settlements (Van Averbeke and Mohamed, 2006). Initially, this IMT was pursued using the Reconstruction and Development Programme (RDP), which focused more on food security in the community or group favouring the establishment of small schemes. In this period, 64 new irrigation schemes were established, adding up to 2400 hectares to the total smallholder irrigation scheme area (Gibb, 2004). Irrigation methods used within the schemes included mechanical pump and sprinkler technologies. In response to political changes in the country during 1990-1994, the Independent Development Trust took over the funding of projects like these and later followed by provincial departments of Agriculture, Health and Public Works as organs of the state (Van Averbeke and Mei, 1998).

As the changes in the country continued, the overall development policy of South Africa changed from RDP to Growth, Employment and Redistribution Policy (GEAR). The aim of the GEAR was to pursue economic growth through private sector development. Therefore, existing irrigation schemes were acknowledged as important resources for economic development, which needed revitalisation first. Also, the IMT period was connected to GEAR because it promised to improve the lives of poor people by means of a process that empowered them to take control of their own resources and destinies (Van Averbeke and Mohamed, 2006).

As with the other eras, the IMT was also not without concerns and, in this regard, Perret (2002) noted four concerns. The first concern was that the original design and aim of most smallholder irrigation schemes were subsistence-oriented, thereby using inexpensive designs that were meant for subsistence farming through surface irrigation (e.g. furrows to convey water from a weir or a dam). Secondly, there was generally little participation by irrigators from the beginning, no local organisation, and most land rights were granted to men, while women were the actual irrigators. In addition, this was also called the smallholder irrigation families period, when land rights were granted to men who became migrant labourers, relocating to cities, industries, and mines and consequently leaving women and pensioners behind to remain in the homesteads and scheme holdings to perform extensive food crop and livestock farming, with weak or unclear property rights on land and water resources. Thirdly, most schemes were characterised by heavy operation and maintenance costs, yet most irrigators were subsistence farmers in a weak agribusiness environment. High costs were a result of sophisticated technologies that were introduced such as pumps and sprinkler irrigation at certain schemes by hired consultants because of infrastructure degradation. The fourth and last concern with IMT was the withdrawal of any support in most schemes by provincial governments since some schemes were declining and some were non-operational for a longer period. Some of the reasons for non-operation and declines of the schemes include inadequate institutional structures, a lack of participation and people involvement, poor operational management setup, and infrastructure deficiencies.

To address some of the aforementioned challenges, the Revitalisation of Smallholder Irrigation Schemes (RESIS) in Limpopo Province was then born. The revitalisation process started from rehabilitation and was later modified to revitalisation. Rehabilitation was an infrastructure-driven style of intervention as compared to revitalisation. The revitalisation was a much broader-based intervention covering a wider range of activities linked to successful small-scale irrigated agribusiness, which include enterprise planning, human capital development, empowerment and access to information, repair, and redesign of infrastructure (Veldwisch and Denison, 2007).

The RESIS programme in Limpopo Province commenced around 2004 when the discussion was about existing and new irrigation schemes (De Lange, 2004). Consequently, the management skills that were needed for irrigation schemes were acquired during the Water-Care Programme and formed the foundation of RESIS implementation plans. The main idea behind the RESIS programme was to empower farmers to manage irrigation schemes. This was facilitated through the election of farmer management committees to take charge of scheme management. Ultimately, the committees played active roles such as capacity building to permit smallholder farmers to grow as successful agricultural producers, marketers as well as managers. Central to the success of the RESIS programme was access to inputs and outputs markets such as mechanisation services, produce markets, and other factors of production. Furthermore, the formation of SMMEs around the schemes to fuel local economic growth formation of joint ventures to have a consistent supply of particular commodities was one of the strategies pursued under the RESIS programme (De Lange, 2004).

Smallholder irrigation schemes in South Africa have been unsuccessful in achieving their intended goal (Van Averbeke et al. in Mkeni, 2010). The reasons for this include socio-economic, political, edaphic, design factors and lack of farmer participation (Bembridge in Mkeni, 2010) and limited crop production knowledge (Machethe et al., 2004). It is nearly 38 years since the WRC made its first enquiry into smallholder schemes in South Africa, when it commissioned Legoupil of CIRAD in 1985 to participate in an irrigation workshop and advise on irrigation planning and development. Based on visits to smallholder schemes in different homelands, Legoupil (1985) concluded that "… smallholder irrigation, in spite of large-scale investment is only marginally effective". Irrigation is failing to provide high production yields and is affected by a whole range of problems, namely, technical, financial, management, training, agricultural policy, and social, to mention a few. There were only 206 schemes that were operational in 2011, while 90 were not. The operational status of the six schemes was unknown. Possible barriers and constraints on 164 of these schemes were poor management (50% of the cases), infrastructure problems (15%), water inadequacies (13%), conflict (12%), and theft (7%) (Van Averbeke et al., 2011). These constraints suggest that human (capacity) and social-institutional problems were at the core of the reasons for farmers performing below the expected potential as identified by (Bembridge, 2000; Kamara et al., 2001; Shah et al., 2002; Tlou et al., 2006; Stevens, 2006; Speelman et al., 2008; Yokwe, 2009; Mkeni et al., 2010). Poor performance and equipment were associated with poor maintenance of infrastructure; high energy pumping costs involved; a lack of institutional support in terms of credit, marketing, and draught power; a lack of competent extension staff; lack of appropriate farmer training; conflict and weak local farmer organisation (Bembridge, 2002; Mkeni et al., 2010; Stevens and Ntai, 2011).

These factors have led to a situation of a steady decline in small-scale irrigation farming, where the majority of small-scale farmers are not meeting their subsistence requirements and only a few produces a surplus, necessitating them to generate income from other livelihood activities like working in mines and neighbouring commercial farms (Cousins, 2012). At present, crop production occurs mostly in home gardens, explaining why irrigation farming only serves as a source of additional food for a large proportion of rural households (Vink and van Rooyen, 2009; Aliber and Hart, 2009; Cousins, 2012). A second possible reason for small-scale irrigation farmers finding it challenging to succeed in small-scale farming is the tough competition from commercial agriculture and the food supply system in South Africa (Laker 2004; Ramabulana, 2011). Within the context of these challenges, it is perhaps not surprising that most small-scale agricultural production on irrigation schemes is undertaken to supplement household food supply and only a small proportion of the production is sold.

2.3.2 Role players in small-scale irrigation

There are numerous role players in smallholder irrigation in South Africa as shown in Table 1.

Table 1. Role players in smallholder irrigation in South Africa and their roles

Stakeholder	*Role*
Water Research Commission (organisation)	For research and publication of scientific studies regarding irrigation at small-scale level.
South African Irrigation Institute (SAII)	For providing training and skill transfer on irrigation technology use and other related knowledge.
All spheres of government (national, provincial and local)	To participate in policy development, planning and implementation of the irrigation system; provide extension support as well as linking financial institutions to small-scale irrigators; linking small-scale irrigators with different service providers.
Engineers	To design and develop the irrigation technologies.
Small-scale producers	These are the target groups – the users of the irrigation system
Academics	To produce specialists in the sector and also research the sector.

The role players in smallholder irrigation and their roles in Limpopo Province are outlined in Table 2.

2.3.3 Size of small-scale irrigation

In South Africa, there are approximately 302 small-scale irrigation schemes, with a combined command area of 47 667 hectares. It is estimated that 1.6 million hectares are under irrigation in South Africa (DWS, 2016). This amounts to about 1.5% of the agricultural land or 10% of the cultivated area (BFAP, 2011). An investigation by de Lange (1994) indicated that there were approximately 150 000 small-scale irrigators, categorised into three broad groups:

- Independent irrigation farmers, who privately accessed and applied water to their farms.
- Holders of allotments on irrigated community gardens; and
- Plot holders on small-scale irrigation schemes.

Du Plessis et al. (2002) added a fourth category comprising backyard or home-garden irrigators, who irrigate crops on parts of their residential sites. General agreement exists that about 100 000 hectares are farmed by approximately 250 000 smallholder irrigators contained in these four groups, and that approximately half of them are located on small-scale irrigation schemes (Backeberg et al., 2006; Bembridge, 1997).

Table 2. Role players in smallholder irrigation in Limpopo Province and their roles

Stakeholder	Role
Limpopo Department of Agriculture, Rural Development and Land Reform	Implement the irrigation system Provides extension support and advisory services Provides inputs subsidies Link financial institutions to small-scale irrigators Link small-scale irrigators with different service providers. Help with infrastructures and sometimes with maintenance.
National Department of Agriculture, Rural Development and Land Reform	Participate in policy development, and planning related to the irrigation system Support the implementation of the irrigation system by the Provincial Department of Agriculture
Department of Water Affairs and Forestry	Builds and finances main structures (i.e. weirs) Subsidises water users associations Legitimises water users associations
Research Institutions (WRC, ARC, NAMC, and HRSC)	For research and publication of scientific studies regarding irrigation at small-scale level.
South African Irrigation Institute (SAII)	For providing training and skill transfer on irrigation technology use and other related knowledge.
Retailers and wholesalers as private organisations	Selling irrigation parts/equipment to main and replace irrigation parts Provide credit for inputs Provide information on inputs
Engineers	To design and develop irrigation technologies.
Small-scale producers	These are the target groups – the users of the irrigation system
Academics	To produce specialists in the sector and also research the sector Provide market information Provide input information Conflict management
Traditional leaders	Conflict management Facilitates interaction with external stakeholders
Cooperatives	Provide market information Provide input information Provide credit/loan Provide easy access to input markets Provide easy access to output markets Provide scheme infrastructure maintenance
Other community members	Provide credit/loan Provide Scheme infrastructure maintenance

Source: Keetelaar (2004); Mwadzingeni et al. (2020); Van Averberke et al. (2011)

In Limpopo Province, the apartheid government established 171 smallholder irrigation schemes to improve the livelihood of smallholder farmers and their families. The value of assets in the irrigation schemes is estimated at R4 billion. These schemes were administered in a top-down manner with emphasis on food self-sufficiency (Machethe et al., 2004). There are over 18 500 hectares of smallholder irrigation in Limpopo Province. Productivity is generally low, and farmers' incomes are often below subsistence levels. A study by Stewart Scott Consulting Engineers (1998) of eleven irrigation schemes in Limpopo Province found several constraints on the development and viability of irrigation schemes. These include small plot sizes, allocation of plots to individuals not interested in farming, inadequate access to credit, inadequate infrastructure, and a lack of interaction between farmers and extension officers. The study also found positive trends that groups of commercially oriented farmers were emerging in some of the irrigation schemes. These farmers have successfully developed farms of up to five hectares on certain irrigation schemes producing high-value crops and taking advantage of market opportunities (Machethe et al., 2004). Smallholder irrigation in Mpumalanga Province largely comprises emerging commercial farmers, most of whom are involved in sugarcane production (Bembridge, 2000; Fanadzo et al., 2011). According to Van Aveberke et al. (2011), there were 19 irrigation schemes in Mpumalanga in 2010. Of these, only seven were operational.

2.3.4 Irrigation technologies used by small-scale farmers

In South Africa, about 33% of farmers used sprinkler irrigation, 11% used the drip irrigation system and 56% used surface irrigation systems (Ciência and Santa, 2010). Sprinkler irrigation is mainly utilised by commercial farmers and, therefore, less adjustable to small farms. According to Van Averberke et al. (2011), 302 smallholder irrigation schemes in South Africa use the following irrigation systems: gravity-fed surface (81), pumped surface (20), overhead (170) and micro (25). Overall, 206 schemes were operational and 90 were non-operational. The operational status and the type of irrigation system used for six irrigation schemes were unknown. In Limpopo Province, the irrigation systems used, and the number of irrigation schemes involved were as follows: gravity-fed surface (61), pumped surface (14), overhead (71) and micro (24). Out of the 170 irrigation systems within the province, 69 were non-operational. Reasons for the schemes to be non-operational are many and vary by context and would consequently need scheme-specific solutions. Hence, scholars in recent discourses have advocated for scheme-specific solutions to better respond to the broad diversity of challenges experienced countrywide when it comes to smallholder irrigation schemes (Fanadzo and Ncube, 2018; Matthews, 2019). In Mpumalanga, the irrigation systems used, and the number of irrigation schemes involved were as follows: gravity-fed surface (4), pumped surface (0), overhead (15) and micro (0).

2.4 Efficiency of Irrigation Water Use

2.4.1 Water use efficiency and how it can be enhanced

Efficient irrigation water use means that farmers obtain the same amount of output using less water or cultivating a larger area of land using the same amount of water. Efficient irrigation water use technology enables smallholder farmers to grow higher-value, more water-intensive crops using the same amount of water (International Finance Corporation, undated). Wallace (2000) noted that more agricultural production will need to come from using the existing land and water due to their scarcity. This calls for higher water use efficiency. It is estimated that 30% of the water destined for irrigation is lost during storage and conveyancing globally (Bos, 1985). Of the remaining 70% that reaches the fields, further losses occur through runoff and/or drainage (Wallace, 2000). Globally, most irrigation systems are said to perform poorly when it comes to water use efficiency, and this suggests that the potential to increase water use efficiency is large. According to Speelman et al. (2007), large farm sizes are more efficient as compared to small-scale farmers. This indicates that farmers who are paying for water use (i.e. commercial farmers) tend to be more efficient since they use water at a price. Land tenure also plays a significant role in efficient water use as farmers who have full ownership of their land are inclined to be more efficient in their water use.

The efficient and productive use of water in irrigation is critical, although it is multifaceted and often misunderstood. FAO (2012) differentiates between improving (a) water use efficiency, which aims at minimising water losses by improving technical efficiency; and (b) water productivity and profitability, including increased yields through improvement in water, land and agronomic management practices, reduced evapotranspiration, growing high-value crops or engaging in value-adding processes. Considering economic efficiency also helps assess whether returns are maximised, but high economic efficiency does not always equate to irrigation being efficient overall (Qureshi et al., 2011). On-farm irrigation efficiency needs to be considered in the context of scheme-level efficiency, and sometimes efficiency atfarm level may not result in improved scheme level efficiency. The efficient use of irrigation water and the complex spectrum of what this means are important to understand when trying to overcome barriers to the adoption of water-efficient technologies to improve farm productivity and profitability. The barriers to the adoption of water-efficient technologies in small-scale irrigation schemes are a broad and complex mix of institutional, market, infrastructure, and production aspects.

Fundamentally, water is critical for human beings, economic development, and biodiversity, making it one of the imperatives of all natural resources. Hence, from the global level, the United Nations declared water as a human right in July 2010. Likewise, and in conformation with the global policy, water is recognised as a human right in the South African Constitution. The complexity is that several countries are facing the challenge of rapidly growing water demands, fuelled by increasing economic growth and growing population, related to urbanisation, industrialisation, and mechanisation (Walter et al., 2011). Similarly, South Africa is one of the several countries in the world experiencing water shortages. For instance, some of the key challenges South Africa is facing include dwindling water supply levels, the growing competition between water users (Jarmain et al., 2014) and the high and ever-rising demand for fresh water (Hassan and Crafford, 2006; Walter et al., 2011). It is for this reason that South Africa through its 1998 National Water Act asserts that water should be utilised efficiently (DWAF, 1998).

Climate change, which exacerbates the erratic rainfall situation, is also adding to the challenges that South Africa is facing. As a result of these challenges, current water uses are greater than the sustainable natural availability and groundwater is being mined (Conradie, 2002). This water usage in South Africa is by various users and ranges from social to economic. Thus, wide-ranging social and economic uses constitute actual water demands of the different water users in South Africa, such as industries, agriculture, services and households as well as the environment.

Given the wide-ranging social and economic uses of water, major challenges currently experienced and the increasing demand for fresh water that is likely to be higher due to increasing population, the option of Water Use Efficiency (WUE) by various water users needs to be explored. One such user in South Africa is agriculture, as irrigation consumes the bulk of water extracted from various sources, and therefore the efficiency of its use is of utmost importance. This is because agriculture and irrigation matter to the economy of South Africa (Van Niekerk et al., 2018; Reinders, 2011). Since irrigation is an indispensable agricultural practice for food, pasture and fibre production in semi-arid and arid areas, efficient water use, and management are today's major concerns (Koech and Langat, 2018). In the same light, the importance of WUE in irrigation represents the ratio between effective water withdrawals, distinguishing how effective is the use of water in a particular process.

Various factors shape the trends in WUE. The trends in the WUE of irrigated agriculture are affected by a variety of factors, which may be broadly categorised as: engineering and technological factors, environmental factors, socio-economic factors and advancement in plant and pasture science (Koech and Langat, 2018). These analysts argue that engineering and technological factors improve irrigation WUE mainly by reducing water losses. For instance, drip irrigation technology and systems have been reported to improve WUE whilst increasing yields and quality of the produce when compared with other irrigation methods for various vegetable crops (Unlu et al., 2006; De Pascale et al., 2011). Furthermore, improvements regarding plant genetics also have led to the development of high-yielding and disease-resistant varieties with higher WUE. Greater environmental awareness also has prospects of inducing the government and related stakeholders around the world to fund water-saving initiatives with the insight that the saved water is released as environmental flows. Lastly, socio-economic factors, considering the technology adoption and the decision-making processes of irrigation water users, have been noted to be drivers of WUE.

Evans and Sadler (2008) discuss ways to enhance the efficient use of irrigation water through improved management and advanced irrigation technologies. They outline various strategies for improving water efficiency, including the following:

- Redesign of irrigation systems;
- Treatment and reuse of degraded water;
- Reducing evaporation losses;
- Introducing site-specific applications;
- Implementing managed-deficit irrigation; and
- Employing engineering techniques to minimise leaching and water losses to unrecoverable sinks.

Improvements in irrigation practices can enhance water efficiency by reducing the amount of irrigation water required. Management options for improving water efficiency may include the following:

- Mulching for weed control and soil evaporation;
- Reduced tillage techniques for reducing soil evaporation losses;
- Site-specific irrigation which takes into account varying growing conditions across a field (e.g. infiltration rates, varying soil types, and soil chemical properties);
- Decision support processes to enable the prediction of crop water use; and
- Irrigation scheduling.

2.4.2 Role of irrigation technology in achieving high levels of irrigation efficiency

According to Rogers et al. (2014), adjustments in water-use regulations and a decline in water availability due to periodic droughts motivate farmers to invest in efficient irrigation technologies. Schaible and Aillery (2012) claimed that over 50% of vegetable farmers in Florida improved their irrigation systems between 2003 and 2008. This indicated that water-use regulation policies play a role in the adaptation of efficient irrigation technologies since efficient irrigation is directly related to water use in farms (Garb and Friedlander, 2014). Australia has used the upgrade of irrigation infrastructure and provision of subsidies for on-farm improvements as one of their main methods to achieve WUE (Koech and Langat, 2018). Furthermore, these authors noted that the main method of irrigation used in Australia was surface irrigation.

Fundamentally, when water users and particularly farmers are faced with limited resources and irrigation water in this case, they have to make difficult decisions on how best to operate. This is a common problem in various parts of the world. For instance, in Australia, farmers resort to irrigating part of their land and cultivate the rest under rainfed conditions since land is practically unlimited whereas water is a limiting factor of production for them.

Issues related to limited access to freshwater are prevalent in other countries with developing economies in the Middle East and North Africa (MENA) as well as West Asia and North Africa (WANA) (Russell et al., 2007; Oweis et al., 2000). This water-related issues have negatively impacted agriculture in general and the production of some important crops within these regions and, therefore, compelling them to maximise WUE. Consequently, upon the realization that enhancing irrigation technologies used within smallholder farming WUE is necessary for meeting food demand, techniques and practices such as Supplemental Irrigation (SI) were explored in the WANA region (Oweis et al., 2000). According to Oweis et al. (2000), SI is defined "as the application of a limited amount of water to rainfed crops where precipitation fails to provide the essential moisture for normal plant growth". This practice has been reported for its potential to reduce the detrimental effects of erratic rainfall patterns whilst enhancing and stabilising crop yields.

Furthermore, it has been noted that to considerably enhance WUE, in addition to the adoption of SI, water-scarce regions similar to WANA, need to combine this irrigation practice with modification of sowing time (e.g. earlier time) and adjustment (to appropriate) levels of Nitrogen (Oweis et al., 2000).

In the same vein of seeking to achieve WUE in MENA, a different response that was proposed was to reduce demand and correct the allocation of freshwater through pricing mechanisms that will accurately reflect water scarcity (Russell et al., 2007). The argument was that charging a price has the prospect of incentivising technological changes that will economise on the use of the charged quantity like adopting water-saving and efficient irrigation technologies. In short, Russell et al. (2007) proposed the Economic Instruments (EI) as the possible solution for addressing WUE in water-stressed regions such as MENA. On a practical level the EI can be used to manage water by charging the amount extracted (per unit), assigning property rights in the resource (incentivising conservation) and through the provision of subsidy for the technology or practice that encourages water saving. Furthermore, other evidence regarding WUE was reported in Egypt where a drip irrigation system was employed to improve grain and straw yields of the main cereal crop, wheat (El-Rahman, 2009). In the same study, drip or sprinkler irrigation was noted as the proper irrigation systems that can enhance WUE. These irrigation systems were recommended in areas where water is scarce and water demand is higher due to population and industrial development, among other things.

2.4.3 Reasons for not achieving high levels of irrigation efficiency

In Iran and South Africa, the agricultural sector is noted to be the largest consumer and user of fresh water and in such cases, the assertion is that water scarcity can only be avoided through water conservation (Rouzaneh et al., 2020; Van Niekerk et al., 2018). Additionally, agricultural WUE in Iran is about 35%, which is low compared to developed countries where it is at least 70% (Rouzaneh et al., 2020). In response to the water scarcity crisis, the Iranian government tried to facilitate the adoption of efficient irrigation systems through subsidies and the provision of long-term loans at low interest to farmers, increased supply of irrigation equipment and extension services to speed up the process of the adoption of efficient irrigation systems (Rouzaneh et al., 2020).

However, Russell et al. (2014) argued that subsiding irrigation systems may lead to incorrect adoption of irrigation technologies and reduces incentives to develop and adopt efficient irrigation systems. Farmers are more likely to adopt irrigation systems that are subsidised due to low market prices and thus, will lead to an inefficient outcome over time. Hence, subsiding irrigation technologies results in an inefficient over-allocation of water resources (Russell et al., 2007).

In support, there have been reports that Iran's adoption of efficient irrigation technologies remained low and worldwide acceptance of drip irrigation as one of the most efficient irrigation systems is at most 4% of the total irrigated area (International Commission on Irrigation and Drainage (ICID, 2012) as cited by (Rouzaneh et al., 2020). Moreover, previous studies have failed to acknowledge farmers' post-adoption experience and farmers' overall perception towards technology and thus, have an impact on the continual use of irrigation systems. Famers' discontinued use of irrigation systems mainly arises from how such technologies are designed and presented to the farmers (Rouzaneh et al., 2020).

According to Lopus et al. (2017), farmers' involvement in designing technologies and considering farmers' needs, expectations and socio-economic characteristics are likely to increase the adoption of irrigation technologies. Therefore, evaluation of farmers' satisfaction and perception post-adoption of irrigation technologies is highly recommended to improve such systems and their reception by farmers. Moreover, farmers' satisfaction with agricultural innovation is an explanatory factor to the success of agricultural innovations (Rouzaneh et al., 2020). For example, pressurised irrigation methods such as drip and sprinkler technologies are generally considered less labour-intensive whilst they also have significantly higher WUE (Koech and Langat, 2018). All these advantages are likely to cause farmers to be inclined to adopt them, especially in countries like South Africa where there are issues of water shortage and limited manpower due to ill-health.

According to Masere (2015), extension agents play an important role in transmitting technologies from research institutions, and governmental and non-governmental institutions to small-scale farmers. They therefore play an important role in enhancing the adoption of new technologies and nurturing development in rural agricultural communities. Moreover, most new agricultural technologies have been transferred to farmers by extension officers in most African countries. However, the adoption of new technologies has been poor and thus, deterioration of farm production and livelihoods of small-scale farmers in Zimbabwe (Masere, 2015). In support, about 70% of farmers in Lesotho do not consider extension services as significant in irrigation management systems and therefore, degrade the credibility of extension services in Lesotho (Stevens and Ntai, 2011).

Moreover, farmers rejected most technologies that are recommended to them as they do not cater for their needs. Therefore, a top-down approach by government officials and extension officers has led to poor adoption of recommended technology and as such technologies fail to address farmers' needs according to their level of importance (Masere, 2015). Additionally, Wheeler et al. (2017) argued that extension services play different roles in both developing and developed countries. For instance, in developed countries, extension services play a significant role in the adoption of hard technology as compared to developing countries. This indicates that extension service is often more effective in developed countries whereby it addresses the needs of the end-users (farmers) compared to developing countries. Nonetheless, extension services are appropriate and needed for both developed and developing countries, especially in developing countries where a majority of the farmers are illiterate and face many challenges that would require advisory services.

2.5 Technology Adoption in the Context of Small-scale Irrigation

2.5.1 The process of technology adoption

Diffusion of Innovation (DOI) is a theory popularised by American communication theorist and sociologist, Everett Rogers, in 1962 that aims to explain how, why, and the rate at which a product, service, or process spreads through a population or social system. In other words, the diffusion of innovation explains the rate at which new ideas and technology spread. The end-result of this diffusion is that people, as part of a social system, adopt a new idea, behaviour, or technology. Adoption means that a person does something differently than what they had previously. The key to adoption is that the person must perceive the idea, behaviour, or product as new or innovative. It is through this that diffusion is possible. The diffusion of innovation theory is used extensively by change agents to understand the rate at which individuals and communities are likely to adopt a new technology, approach or service. Adoption of a new idea, behaviour, or technology (i.e. "innovation") does not happen simultaneously in a social system; rather it is a process whereby some people are more apt to adopt the innovation than others. When promoting an innovation to a target population, it is important to understand the characteristics of the target population that will help or hinder the adoption of the innovation. According to Bontsa et al. (2023), people who adopt an innovation earlier demonstrate different characteristics than those who adopts an innovation later.

Technology adoption has been investigated by a number of diffusion of innovation theories. The most influential has been by Rogers (1995) who framed the adoption of innovation as a life-cycle made of five adopter categories. These are as follows:

1. Innovators: Characterised by those who want to be the first to try the innovation. These are courageous individuals ready to try out new things. They are risk-takers, price-insensitive, and can cope with a high degree of uncertainty. Innovators are crucial to the success of any new technology or service, as they help it to gain wider acceptance.
2. Early Adopters: Characterised by those who are comfortable with change and adopting new ideas. These are referred to as “influencers” or “opinion leaders” who are ready to try out new things but exercise a bit more caution than the innovators. Early adopters are often regarded as role models within their social system.
3. Early Majority: Characterised by those who adopt new innovations before the average person. However, evidence is needed that the innovation works before this category will adopt the innovation. These are people who are careful but ready to accept change quicker than the average.
4. Late Majority: Characterised by those who are sceptical of change and will only adopt an innovation after it has been generally accepted and adopted by the majority of the population. These people are often technologically shy and cost-sensitive.
5. Laggards: Characterised by those who are very conservative – they are the last to make the changeover to new technologies. These people resent change and may continue to rely on traditional products or services until they are no longer available. In other words, they typically

only adopt the new technology when virtually forced to. This category is the hardest to appeal to.

Rogers provides the distribution of the five adopter categories as follows: Innovators represent the first 2.5% of the group to adopt an innovation, followed by 13.5% as early adopters, 34% as early majorities, 34% as late majorities, and finally, 16% as laggards (see Figure 1). Note that the size of the laggard category is much larger than that of the innovators category on the opposite end of the spectrum.

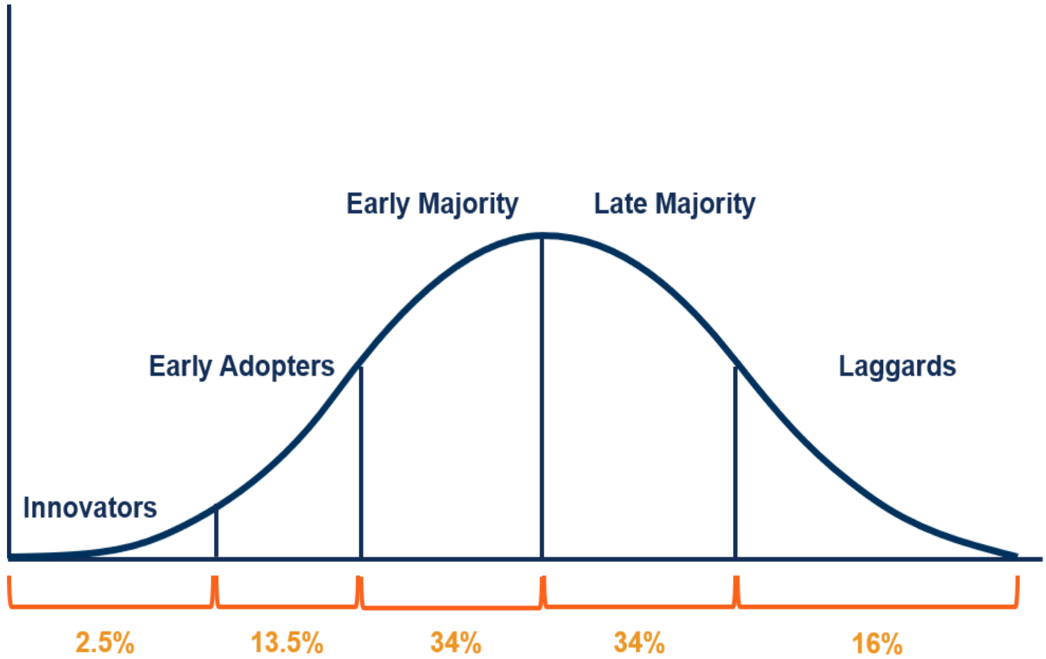

Figure 1. Rogers' adoption/innovation cycle showing the distribution of different categories of adopters of a new technology over time

Source: Rogers (1995)

The stages by which a person adopts an innovation, and whereby diffusion is accomplished, include awareness of the need for an innovation, decision to adopt (or reject) the innovation, initial use of the innovation to test it, and continued use of the innovation. Five main factors influence the adoption of an innovation, and each of these factors is at play to a different extent in the five adopter categories.

1. Relative advantage – The degree to which an innovation is seen as better than the idea, programme, or product it replaces.
2. Compatibility – How consistent the innovation is with the values, experiences, and needs of the potential adopters.
3. Complexity – How difficult the innovation is to understand and/or use.
4. Trialability – The extent to which the innovation can be tested or experimented with before a commitment to adopt is made.
5. Observability – The extent to which the innovation provides tangible results.

2.5.2 Determinants of technology adoption in small-scale agriculture

Improving agricultural productivity in the developing world in general and sub-Saharan Africa in particular, has become an urgent need, dictated by population growth, uncertainty in global food markets, changing consumption patterns of food commodities, as well as the desire to meet important milestones in food and nutrition (World Bank, 2007). The findings from a study conducted at the New Forest irrigation scheme in Mpumalanga Province of South Africa from 2013 to 2014 revealed the importance of small-scale farmer coordination and grouping of farmers with similar circumstances to enable them to either benefit from synergies, or to make it easier for training and sharing of information; the need to address cooperative governance issues, facilitation of farmer collective action, enforcing rules and regulations of engagement, and linking the irrigators more effectively with input and output markets (Ncube, 2017).

Research conducted in Tanzania and Cameroon in 2017 established that incomplete irrigation infrastructure is among the barriers and opportunities for improving irrigation productivity and profitability (Makarius et al., 2017). Irrigation infrastructure includes water diversion, irrigation canals and water distribution off-takes. The study concluded that infrastructure and the layout of irrigated plots play an important role in determining the efficiency of distribution and the timing of water supply. The study also found that governance challenges both within and outside the smallholder farmer group, access to farming implements and ownership thereof, are determinants of adoption of technologies, ideas or services.

Diffusion of innovation in agriculture is a complex process wherein the success of this process is governed by various factors, which include the environment, socio-cultural factors, stakeholder participation and technology characteristics (Senyolo et al., 2018; Tuan et al., 2018). According to Senyolo et al. (2018), in order to leverage and improve adoption, stakeholders need to interrogate the adoption of such innovations and technologies in alignment with the needs of farmers. Nonetheless, understanding this complex process within agriculture together with the factors that influence this process is useful in predicting the likelihood of adoption as well as projecting whether a new technology will succeed (Sevcik, 2004). Therefore, in the case of the current study, it would be helpful to understand some of the factors that may shape farmers' use of irrigation technologies. The renowned scholar in the area of innovation diffusion, Rogers (2003), noted five critical attributes of innovation that could be used to explain and predict adoption rate, namely, complexity, trialability, compatibility, relative advantages, and observability.

However, Tuan et al. (2018) contend that exogenous factors such as policy, climate change and unforeseen event may influence the adoption decision of a new technology, regardless of whether or not the technology is tested and that its advantages are evident. The authors posit that opinion leaders and change agents are among the noted exogenous factors (Tuan et al., 2018). This is becausechange agents are known to encourage the adoption of new innovations. By the same token, the change agents have the potential to slow down or hold up the adoption when they perceive it to be undesirable. Hence, Rogers (1995) defines change agents as those individuals who influence clients' innovation decisions in a direction considered desirable by change agencies and opinion leaders as those individuals who can influence others' attitudes or behaviour informally in a desired manner with relative frequency. These could be other farmers within a particular irrigation scheme.

According to Tuan et al. (2018) change agents work hand in hand with opinion leaders to improve the impact of diffusion activities within a social system because they are characteristically more innovative than others. It is for this reason that in this current study, it was considered important to be conversant with the change agents and opinion leaders. Whilst traditional research on diffusion places farmers at the centre of their diffusion process, Goss (1979) contended that these traditional systems tended to hold farmers accountable for their actions in adopting an innovation. Understanding both farmers' decisions and change agents' roles will provide a holistic view and contribute to our understanding of the diffusion process in this regard. Accounting for the above aspects in the context of the current study will enrich the study outcomes and help the researchers to account for the pro-innovation bias.

Masere (2015) evaluated the role of extension in the adoption of new technology by small-scale resource-constrained farmers in Zimbabwe. The key aim of the study was to identify the main factors influencing small-scale farmer innovation and adoption of recommended technologies. Factors that were found to be significant included small land sizes, high cost of technology, a lack of capital to buy technologies, a lack of access to both credit facilities and input-output markets, and a lack of adequate information support. The findings of the study also revealed that technologies that are being recommended by the extension officers do not correlate with the needs of farmers and thus lead to poor adoption of the recommended technologies. Farmers' perception of new technologies should, therefore, be considered during the development stage of such technologies and embrace their indigenous knowledge for them to be able to utilise such technologies over a prolonged period. Furthermore, previous research noted that irrigation management tools need to be unsophisticated and understood by the growers for them to be adopted (Jarmain et al., 2014).

Additionally, the adoption of new technologies mainly depends on the education status of the farmers, age, and size of land and location of the farm (Bijay et al., 2018). Farmers who live close to the urban market and have access to technologies tend to adopt efficient irrigation systems as compared to farmers in rural areas. Farmers may also adopt efficient irrigation technologies to maximise profit and minimise risks associated with unpredictable weather conditions and inconsistent rainfall patterns that will reduce water availability. Hence, the adoption of an efficient irrigation system is high in commercial agriculture as compared to small-scale farmers (Bijay et al., 2018).

Various factors have been documented as enablers and dis-enablers for the adoption of innovative technologies, ideas, and approaches by smallholder farmers. These factors are:

1) Ability to pay which refers to farmers' capability of paying for and owning or using the newly

introduced technology. This depends on farmers' level of income, access to credit, and other sources of financing for agricultural activities.

2) Vulnerability refers to the susceptibility of farmers to adverse conditions that may result from using a new technology or from deviating from their usual agricultural practice. This susceptibility may reduce the farmers' ability to turn out the produce they have been relying on for their sustenance. Farmers who are more vulnerable to risks prefer taking less risk and so will tend to be the late adopters or laggards in Roger's innovation adoption cycle (see Figure 1). There is therefore some threat of production failure (risk) involved in adopting a new technology.
3) Scale of production refers here to farmers' range of production possibilities. One can distinguish between the physical range of this possibility, which will be how much land the farmer has and can bring to production and the range in terms of diversity, meaning the number of different production associations the farmer practices at any given time. Each of these possibilities is taken to refer to farmers' scale of production in this study wherever applicable.
4) Adaptability to local conditions refers to the ability of new technology to be used with minimal disruptions in the formalized system of functioning of local agriculture. It includes the ability for new technology to be flexible and adjustable enough to facilitate its integration into the local agricultural system.
5) Long-term considerations refer to the assessment made by farmers of how sustainable this technology can be. It is a consideration of the dependability of a new technology.
6) Suspicion towards new technologies is born from a history of failed attempts at introducing viable innovations in small-scale agriculture in the study areas. It refers to a misgiving about the true intentions of the new technology.
7) Endorsement by opinion leaders refers to the backing or approval of the new technology given by people who matter in the communities and lives of small-scale farmers.
8) Access to information refers to the ease of having information on the new technology under consideration. Information here refers to knowledge about the existence of a technology, knowledge of what the technology can or cannot do, its limitations, and so on. Information can be tainted or biased when small-scale farmers receive it (even from trusted sources such as agricultural extension services and other opinion leaders) for a variety of reasons.

According to the International Finance Corporation (undated), the adoption of water-use efficient technology is affected by the following factors:

a) Awareness of the technology and required skills to use it;
b) Required infrastructure to enable farmers to reap the benefits of using the technology;
c) Access to finance;
d) Access to markets;
e) Access to inputs; and
f) The regulatory environment.

2.5.3 Methodological issues for identifying factors affecting technology adoption

In their study, Bijay et al. (2018) used a multinomial fractional regression model to examine the adoption of irrigation technologies by cotton farmers in 14 states of the United States of America. The research findings revealed that older farmers were more likely to allocate more land to furrow irrigation and the level of education was also found to be positively significant. Educated and young farmers were more likely to allocate a higher proportion of land to drip irrigation as the most water-efficient irrigation system. Moreover, farm location also influenced the allocating of more land to drip irrigation system since farmers in the Southern Plains were found to allocate more land to drip irrigation as opposed to other irrigation systems. Other variables that were found to be significant include cover crop and source of information. Therefore, this indicates that increasing extension services to farmers is more likely to encourage farmers' adoption of efficient irrigation technologies. These results are supported by Tang et al. (2016) who argued that educated farmers in China are more likely to adopt water-saving technologies.

In their study, Abebe et al. (2020) on 'Irrigators' willingness to pay (WTP) for the adoption of soil moisture monitoring tools in south-eastern Africa, the Contingent Valuation (CV) and Tobit models were used to investigate farmers' WTP for soil moisture monitoring technologies and how this WTP relates to the current market prices. The results of the study revealed that the age of the farmer and access to information had a significant influence and older farmers were less willing to pay for the sensor technology and more hesitant to pay for new technologies. However, this is in contrast with the findings of Mathlo (2014) who indicated that farmers with tenure rights and more experience in farming tend to adopt new agricultural technology and take risks associated with adopting new technologies. Additionally, the results also indicated that paying for irrigation water had a direct influence on farmers' WTP for soil moisture tools. Nonetheless, there is still room for co-investment by other stakeholders to facilitate the adoption of soil moisture monitoring tools (Abebe et al., 2020).

In the case of Iran, Rouzaneh et al. (2020) used the European Customer Satisfaction Index (ECSI) to quantify the level of farmers' satisfaction derived from adopting new irrigation system. This was to improve an understanding of why farmers may choose to adopt or not adopt new irrigation systems. In this regard, the findings of the study revealed that the value attached to the irrigation system and its hardware quality, the quality of services rendered to farmers and how they perceive the provider of irrigation systems have an impact on improving farmers' satisfaction with new irrigation systems.

Rogers et al. (2014) examined the economics of seepage and drip irrigation systems. The study aimed to discuss the economic factors influencing the selection of agricultural irrigation systems and the Net Present Values (NPVs) of both irrigation systems were compared over ten years. The NPV was projected as a sum of annual net returns. The findings of the study revealed that tomato farmers in southwest Florida will benefit more if they discontinue using the seepage irrigation system for the drip irrigation system, since drip irrigation has higher net returns and potential increase in yields and is the main determinant of profitability of efficient irrigation systems.

In Nigeria, Adebayo et al. (2021) identified the determinants of decisions to adopt cocoa varieties using a Multivariate Probit Model. The study found that farmers belonging to cooperatives had a greater likelihood of adopting all five technologies considered. Other factors that positively affected technology adoption were age, credit access, education and extension contact. Household size, on the other hand, negatively influenced the adoption of new crop varieties.

In Kenya, Musafiri et al. (2022) used Multivariate and Ordered Probit models to identify the determinants of joint adoption of climate-smart agricultural practices. The adoption of these practices was found to be influenced by the household head's gender, education, age, family size, contact with extension agents, access to weather information, arable land, livestock owned, perceived climate change, persistent soil erosion, and soil fertility.

In Mpumalanga Province, Oduniyi et al. (2022) used a triple hurdle regression model to analyse the factors influencing farmers' awareness and adoption of sustainable land management practices. Factors that were found to increase farmers' awareness of sustainable land management practices included farm input source, availability of farm inputs, extension frequency, water sources and marital status.

2.5.4 Role of change agents in the adoption of irrigation efficient technologies

According to Masere (2015), over the past five decades, the development of improved agricultural technologies and the eventual adoption of these technologies by farmers resulted in major changes in agriculture. The adoption of yield-increasing and labour-saving technologies has enabled farmers to increase yields, expand operations, and increase efficiency ratios. Modern technology in agriculture also has reduced the need for human labour and has resulted in farm production becoming increasingly concentrated on fewer and fewer farms. Miller (2018) states that agricultural extension has been at the heart of this development and is responsible for the diffusion of agricultural technologies and innovations for the improvement of agricultural production. However, the process of technology and innovation diffusion remains a complex process, particularly in the smallholder sector of agriculture. It is challenged by a variety of socioeconomic and institutional factors, which make the adoption of technology by farmers a difficult task.

Tuan et al. (2018) contend that other exogenous factors may influence the adoption decision of a new technology, regardless of whether the technology is tested and its advantages are evident. The authors posit that opinion leaders and change agents are among the noted exogenous factors (Tuan et al., 2018). This is because change agents are known to encourage the adoption of innovations. By the same token, the change agents have the potential to slow down or hold up the adoption when they perceive it to be undesirable. Rogers (2003) defines change agents as those individuals who influence clients' innovation decisions in a direction considered desirable by change agents and opinion leaders. They are individuals who can influence others' attitudes or behaviour informally in a desired manner with relative frequency. These could be other farmers within a particular irrigation scheme.

According to Tuan et al. (2018), change agents such as farmers work hand in hand with opinion leaders to improve the impact of diffusion activities within a social system because they are characteristically more innovative than others. Whilst traditional research on diffusion places farmers at the centre of their diffusion process, Goss (1979) contended that these traditional systems tended to hold farmers accountable for their actions in adopting an innovation. Nonetheless, understanding both farmers' decisions and change agents' roles will provide a holistic view and contribute to our understanding of the diffusion process. Consequently, accounting for the above aspects in the context of the current study will enrich its outcomes.

Smallholder farmers do not always adopt new technology recommended to them by change agents. In South Africa, most of the technologies are disseminated by public extension agents from the Department of Agriculture, Land Reform and Rural Development (DALRRD) (DAFF, 2016). DALRRD is mandated to provide a plethora of services, including technical, advisory and regulatory services, to different farmers. Furthermore, DALRRD is responsible for training farmers on various agronomic practices and for the dissemination of technologies (DAFF, 2016). In addition to these roles, the DALRRD extension agents play the important role of taking feedback from farmers to technology developers (including seed houses, fertilizer companies, and research institutes). The government remains the major supplier of all extension and advisory support services to smallholder farmers.

Accessibility of extension services

Access to agricultural extension is essential for sharing information, knowledge, and innovation between farmers and researchers (Loki and Mdoda, 2023). Agricultural extension is involved in public information and education programmes that could assist farmers in using water efficiently (Stevens and Ntai, 2011). Such involvement includes awareness creation and knowledge brokerage on irrigation water technologies, building resilience capacities among vulnerable individuals, communities, and regions, and encouraging broad participation of all stakeholders in using the latest technologies for water efficiency.

Worth (2012) posited that agricultural extension must reorient itself beyond the narrow transfer mindset of technology packages and rejuvenate its vigour for transferring knowledge as the input for modern farming. Stevens and Ntai (2011) found that farmers who had access to extension services adopted farming technologies more than those with no access to such services. Muchesa et al. (2019) and Mapiye et al. (2021) also reiterated that exposure to extension services influences the capacity of farmers to adapt to the use of irrigation technologies for farm production.

Technology transfer

Agricultural extension also aims to transfer agricultural technology and persuade farmers to adopt and use these technologies. These agricultural innovations and new agricultural technologies must be good and superior to the old agricultural techniques used by farmers to be adopted (Tuan et al., 2018). Transfer of technology and persuading farmers to adopt it can be done through on- and off-field training and the use of various digital communication tools. The process of agricultural technology transfer is done in two stages. The first phase entails the transfer and dissemination of technology to farmers. The second stage involves convincing farmers to adopt the technologies on their farms (Ullah and Zafarullahkhan, 2014). Technology transfer and persuading farmers to apply them on farms are generally done by agricultural extension officers who have practical experience in technology dissemination and knowledge of how to work with farmers (Maoba, 2016).

It is worth noting that despite the need for timely and well-targeted information on climatic risks, there are currently several gaps and challenges in providing agricultural technology information to farmers from practitioners. Among them is the non-preparedness of extension organisations to train farmers on how to use the technology after it has been transferred to them. Some of the extension organisations in the developing world are unaware of environmental issues such as climate change impacts, which necessitate the use of water-efficient technologies. Preparedness in terms of documenting climate change scenarios at the grassroots level, the extent of adaptation (individual/community level), mapping vulnerable regions, sustainable indicators, access to real-time data, practical synthesis and interpreting, and better decision-making for a climate change scenario is missing at present.

Training of farmers

According to Wang et al. (2021), training is an effective means to enhance farmers' awareness of new technologies and the understanding of new technology can influence its adoption by farmers. Studies have found that training introduces advanced production techniques to farmers and teaches them how to use technologies, which could change farmers' awareness and cause them to switch from traditional production behaviour to modern production techniques (Asian Development Bank, 2013). Training can be used to teach farmers about efficient irrigation water technologies, which include irrigation scheduling, the use of methods like drip over flood irrigation and increase knowledge on other water-saving technologies.

Previous studies have confirmed that on-site, face-to-face training with practical demonstrations contributes to the adoption of new technologies (Maoba, 2016; Worth, 2012; Makara, 2010). For example, Nakano et al. (2018) indicated that farmer-to-farmer training could encourage farmers to adopt new technology. Stevens and Ntai (2011) found that hands-on and in-field training formats were more effective than one-time, lecture-based training (Ann, 2013). Additionally, Mmbando (2021) pointed out that informal social networks could help disseminate agricultural knowledge and the adoption of agricultural techniques.

2.6 Summary

Chapter 2 reviewed literature on smallholder irrigation nationally and globally, water use efficiency, the concept and process of technology adoption and factors affecting technology adoption. Smallholder irrigation can be an effective way to address the challenges of poverty and food insecurity. This should be achieved using technologies that promote water-use efficiency. Irrigation technologies that are water-efficient in previous studies include irrigation systems such as sprinklers, drip and micro. They also include crop production technologies or practices such as soil mulching, conservation tillage, irrigation scheduling, and soil management. The technology adoption process is complex, and it is affected by numerous factors. These factors have to do with the characteristics of the farmers, characteristics of the technology, the role of change agents, institutions and the socio-economic environment within which smallholder farmers operate

CHAPTER 3: METHODS AND PROCEDURES

3.1 Introduction

This chapter outlines the research approach adopted in conducting the study. The methods and procedures for data collection and the respondents who participated in the study are described. The criteria used for selecting the two irrigation schemes included in the study are also described. The criteria included irrigation scheme performance, type of enterprise, institutional/governance structure, type of irrigation system, size of irrigation scheme, and the support system in place. Details of the irrigation schemes such as their location, size, type of irrigation system, and crop enterprises are discussed. The procedures for selecting the sample and sample characteristics are also described. Given the relatively small number of beneficiaries in both schemes, it was decided to include all the farmers in each scheme (census method). The chapter also describes the tools used in data collection and analysis.

Subsequent sections of the chapter are organised as follows: Section 3.2 describes the selection criteria for the two irrigation schemes included in the study were selected. This is followed Section 3.3 which provides a detailed description of the irrigation schemes in terms of their location, size, types of crops grown, etc. Sections 3.4 and 3.5 discuss how the sample was selected and the methods of data collection, respectively. The characteristics of the sample are discussed in Section 3.6. Issues of data reliability and validity, and ethical considerations are covered in Section 3.7 and 3.8, respectively. Section 3.9 explains how data were analysed.

3.2 Selection of Research Areas

The two irrigation schemes included in this study (Matsika and New Forest) were selected according to the following criteria:

3.2.1 Irrigation scheme performance

It was important to include a scheme that is considered to be performing well and one that is considered to be performing poorly. The rationale for this was that reasons for the adoption or non-adoption of irrigation-efficient technologies are likely to be different in the two types of irrigation schemes. Therefore, selecting irrigation schemes whose performance status is the same was unlikely to provide a complete picture of what affects the adoption or non-adoption of irrigation-efficient technologies. Performance may be proxied by the level of production or yield and profit where farmers are selling their products. At the time of selecting the schemes, there was no information on their production, yield or profit. Therefore, the research team relied on the information provided by the relevant government officials.

3.2.2 Type of enterprise

The selected schemes needed to demonstrate diversity in terms of farming enterprises. It was envisaged that adoption or non-adoption of irrigation-efficient technologies would vary according to the type of farm enterprise involved. Therefore, the selected schemes needed to produce different types of crops/vegetables/fruits.

3.2.3 Institutional/governance structure

The type of institutional/governance structure in place is likely to play a major role in the technology adoption process. Therefore, it was important to ensure there was some form of governance/institutional structure in place in the selected schemes.

3.2.4 Type of irrigation system

The schemes were selected so as to include a diversity of irrigation systems. It was envisaged that the type of irrigation system used would have a bearing on the adoption or non-adoption of irrigation-efficient technologies.

3.2.5 Size of irrigation scheme

The selected irrigation schemes were supposed to be of different sizes as this was expected to affect the adoption of irrigation-efficient technologies. The size of an irrigation scheme was measured in terms of both land area and number of farmers.

3.2.6 Support system in place

The type of farmer support received by irrigation scheme farmers was expected to affect the adoption or non-adoption of irrigation-efficient technologies. Support may be in the form of extension services, finance, and research. The selected schemes needed to have one or more of these support services.

3.3 Description of the Selected Irrigation Schemes

Matsika irrigation scheme was identified as a well-performing scheme while New Forest irrigation scheme was identified as a poor-performing scheme. The classification of the schemes according to their performance was based on the information obtained from the relevant government officials. Details of the two irrigation schemes included in this study are presented in Table 3. These include the location of the scheme, size of the scheme, type of irrigation system used, main crops cultivated and performance status of the irrigation scheme. The irrigation system used at Matsika is micro while flood irrigation is used at New Forest. At New Forest, crops and vegetables are cultivated while bananas are grown at Matsika.

Table 3. Details of Matsika and New Forest irrigation schemes

	Matsika	New Forest
Province	Limpopo	Mpumalanga
District	Vhembe	Ehlanzeni
Local municipality	Thulamela	Bushbuckridge
Village	Matsika	New Forest
Scheme size (ha)	102	22
Number of farmers	54	60
Enterprises	Sub-tropical fruits	Crops and vegetables
Performance status	Good	Poor
Type of irrigation system	Micro-jet	Flood/furrow

Source: Field Survey (2021)

Matsika irrigation scheme is 33 km east of Thohoyandou town and the central business district (see Figure 2). The project started as a dry land project where farmers were planting summer crops. This project was initiated by the Malavuwe sub-tribal authority in early 1982. The scheme is within the Thulamela Municipality in Vhembe District Municipality (VDM) of Limpopo Province. The irrigation scheme occupies an area of about 102 hectares, with a production area of 90 hectares. There are 54 beneficiaries. Currently, the irrigation scheme is producing bananas as the main crop. However, the plan is to also grow macadamia nuts as a cover crop. The Limpopo Department of Agriculture revitalised the Matsika irrigation scheme in 2015 and contracted Mmakoto to construct the infield infrastructure. During this period, the scheme was temporarily not utilised (Van Koppen et al., 2017).

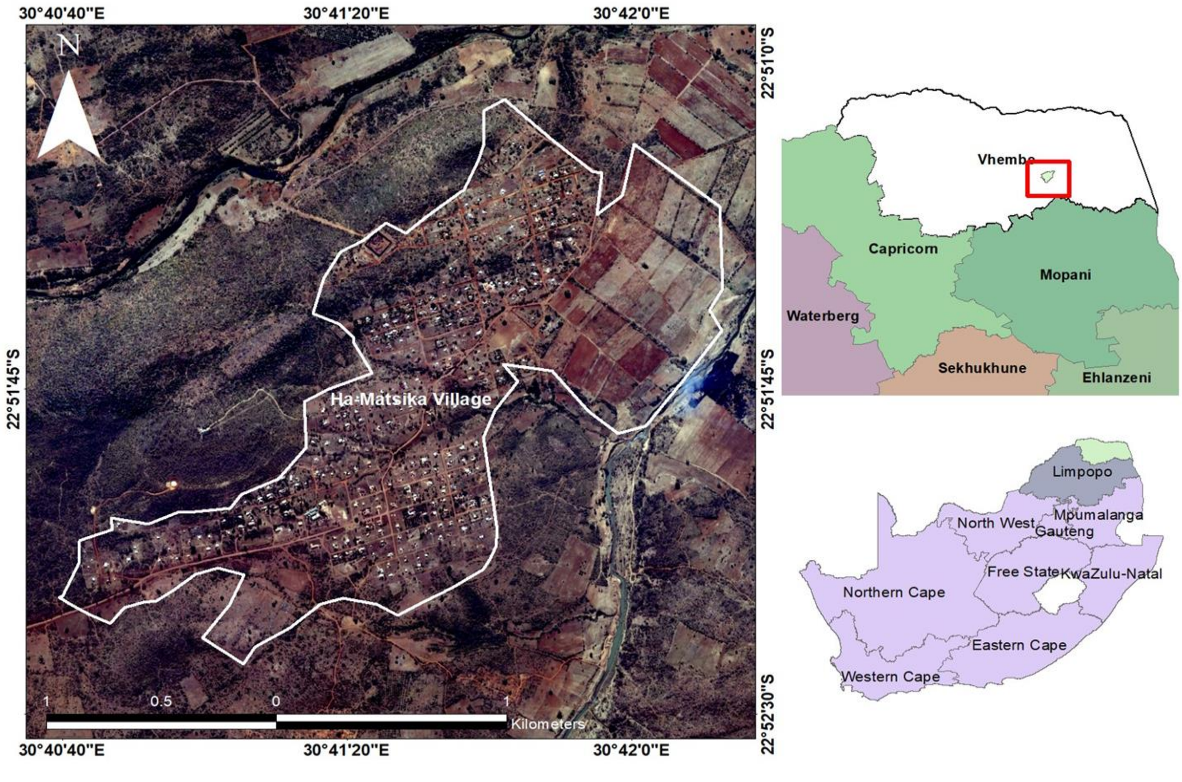

Figure 2. Location of Matsika irrigation scheme

Source: Vhembe District Municipality, 2020/21 IDP-Review

New Forest irrigation scheme is in Bushbuckridge Local Municipality, in Ehlanzeni District Municipality (EDM) of Mpumalanga Province (see Figure 3). According to Ncube (2018), the scheme was established in the 1960s, when the then government took the land from a private company and transferred it to the local people. Black household families were resettled in the New Forest village and allocated one-hectare plots each to farm under irrigation with the purpose of supporting their livelihoods (Ncube, 2018). During the follow-up discussion with the official working in the area in December 2022, he corroborated this and further stated that the scheme was established in 1964. The irrigation scheme occupies an area of about 22 hectares. Sixty active farmers in the scheme grow diverse crops such as maize and vegetables. Maize is sold as green mealies and vegetables include tomatoes, butternuts, chillies and cabbages.

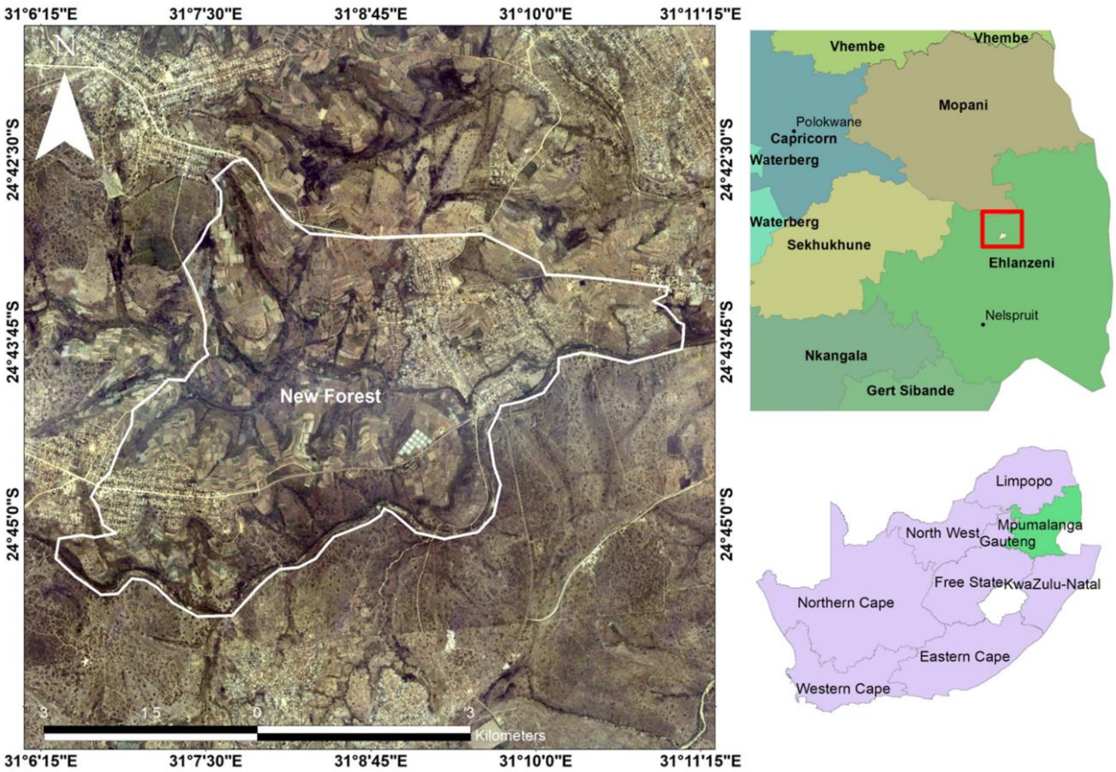

Figure 3. Location of New Forest irrigation scheme
Source: Ehlanzeni District Municipality, 2020/21 Draft and Budget IDP-Review

3.4 Sample Selection

The study employed the census method in selecting the participants. The reason for this was that the total population of farmers in the two irrigation schemes was only 114. Given the relatively small number of farmers in both irrigation schemes, it was decided to include all the farmers in the sample. However, not all farmers could be interviewed as some of them were unavailable for various reasons. The sample included 104 farmers, which is 91% of the total population of farmers.

3.5 Data Collection Methods

Data were collected by means of questionnaires and focus group discussions during November and December 2022. However, key information that informed the survey and FGDs and site visits commenced in 2021 to familiarise the research team with the study area.

At Matsika irrigation scheme, some of the farmers were unwilling to participate in the interviews. This was because they had participated in surveys of this nature in the past, where researchers collected data and never bothered to return to provide feedback or follow up on the issues raised during the research. Thus, a significant amount of time was devoted to reassuring the farmers of the intention of the research team to go back and report on the findings or preliminary results of the study. Another issue was what seemed to be tension between the farmers and the servicing extension officers. Again, the research team had to explain that they were independent but communicated with the government officials and other relevant stakeholders as required by the protocol. Eventually, common ground was reached, and the survey proceeded smoothly. This was useful as it provided context to some of the individual responses of the farmers to the questionnaire questions. A total of 44 out of 54 farmers (i.e. 81% of the total population of farmers) were interviewed.

At New Forest, the farmers were sceptical at the beginning of the interviews but welcomed the research team later. The research team managed to interview 60 farmers, which was higher than the initial total of 48 farmers provided to the research team before the survey.

3.5.1 Questionnaire survey

Trained university students and unemployed graduates were used as enumerators to conduct face-to-face interviews with the farmers (see Appendix A for the questionnaire). Some of the enumerators were fluent in the local language, and this was essential because it allowed farmers to fully understand the purpose of the study and to express their views succinctly. For each scheme, a member of faculty from the universities of Limpopo and Pretoria was responsible for managing the surveys. This assisted the enumerators significantly in instances where they could not clearly respond to the questions raised by the farmers.

3.5.2 Focus group discussions

Focus group discussions were also used to collect data in both irrigation schemes. In this regard, two separate discussions took place in each scheme. The first discussion involved representatives of irrigation scheme farmers and government officials. This was followed by a smaller group of farmers, including members of the management committees of the schemes. The focus group discussions covered various aspects, including answering the following questions: How would you describe current access to the extension officer(s) assigned to the irrigation scheme? What would you say is the role of change agents (extension officers) in the activities of the irrigation scheme? In your opinion, who is the main provider of the extension service on the scheme?

3.6 Sample Characteristics

Table 4 provides information about the farmers participating in the two irrigation schemes, including gender, marital status, age, education, and farming experience in the two irrigation schemes.

Table 4. Characteristics of the farmers in New Forest and Matsika

	New Forest		***Matsika***	
	Respondents	*%*	**Respondents**	*%*
Gender: male	15	25.0	13	27.7
Gender: female	41	68.3	31	66.0
Married	20	33.3	22	46.8
Average age (years)	59	-	63.5	-
Years of schooling	4.7	-	3.0	-
Years of farming	16.1	-	19.6	-

Source: Field Survey (2022)

Table 4 shows that the majority of the farmers at New Forest (68%) and Matsika (66%) irrigation schemes were females. This result is in line with the results of previous studies (GHS, 2016; DAFF, 2016; StatsSA, 2017) that posit that smallholder farming is female-dominated in the rural areas of South Africa. The average age of the farmers ranged from 59 years in New Forest to 63 years in Matsika. These results agree with the General Household Survey (GHS) (2016) findings that in various community-based surveys, on average, farmers in rural areas are older. Sunny et al. (2022) concluded that older farmers can contribute to lower yield returns due to limited energy for farm activities. In both irrigation schemes, there were low levels of education. The average years of schooling of the farmer were three for Matsika and about five for New Forest. This could make it difficult for farmers to comprehend and adopt innovative technologies and information that could help them cope with water scarcity. The proportion of married farmers ranged from 33% at New Forest to 47% at Matsika.

3.7 Reliability and Validity

The questionnaire was pre-tested prior to the actual survey and how farmers answered it revealed consistency in responses. Previous research investigated the farmers' adoption of new technologies and made similar findings of reliability and validity of the research instrument (Makarius et al., 2017; Ncube, 2017; Rouzaneh et al., 2020; Senyolo et al., 2018; Tuan et al., 2018; Van Niekerk et al., 2018). The physical and psychological environment where the data were collected was to be made comfortable by ensuring privacy, confidentiality, and general physical comfort.

3.8 Ethical Considerations

All the data for this study were collected using questionnaires and focus group discussions. Therefore, the privacy and confidentiality of the answers provided by the farmers were protected and stored at the University of Pretoria.

3.9 Data Analysis

The data collected for this study were first captured in Excel and later exported in SSPS for further analysis. To address the research objectives, various techniques were employed to come up with empirical results. Before addressing the research objectives, descriptive statistics in the form of frequencies, tables, charts, and means were used to describe the data. This made it possible to compile information on the socio-economic and farming characteristics of the sampled farmers. The primary reasoning behind this study was to identify the factors influencing the adoption of water-efficient irrigation technologies in smallholder irrigation schemes in Limpopo and Mpumalanga provinces.

3.10 Summary

This chapter described the methods and procedures used in conducting this study. The chapter started by describing the reasons for the selection of the study areas and further explained the reasons why a formal survey was the most suitable method to collect standardised information from the selected sample of farmers. The criteria used for selecting the two irrigation schemes included in the study are described. The criteria used included: determinants of technology adoption in small-scale agriculture, type of enterprise, institutional/governance structure, type of irrigation system, size of irrigation scheme, size of irrigation scheme and support system in place. Concerning the sampling procedure, the census method was employed, given the relatively small number of farmers in both schemes. Both qualitative and quantitative methods were employed in data collection and analysis. Ethical considerations were adhered to in conducting the study.

CHAPTER 4: SOCIOECONOMIC ENVIRONMENT WITHIN WHICH SMALLHOLDER IRRIGATION FARMERS OPERATE

4.1 Introduction

This chapter presents information on the socioeconomic environment within which smallholder irrigation farmers in the two irrigation schemes (Matsika and New Forest) operate. This is important as the socioeconomic environment has a bearing on the activities of smallholder irrigation farmers, including making decisions on technology adoption. A distinction needs to be made between the socioeconomic environment within which smallholder irrigation farmers operate and their socioeconomic status. In simple terms, the former is about the social and economic factors existing in the irrigation scheme and beyond, which affect the socioeconomic status of an individual smallholder irrigation farmer. These include physical infrastructure, employment, education, sources of income, input and output markets, policies, and governance structures, to mention a few. The socioeconomic status of a farmer is about the social and economic standing of the farmer within his/her community. A socio-economic environment constitutes the foundation for all planning. For this reason, national, and regional as well as local development priorities can only be achieved with a better understanding of the socioeconomic environment. It was for this reason that the socioeconomic environment within which smallholder farmers operate in the study areas was assessed at district municipality, local municipality, village and irrigation scheme levels.

Subsequent sections of the chapter are as follows: Section 4.2 discusses the socioeconomic environment at the district municipality level. Section 4.3 describes the socioeconomic environment at the local municipality level. Section 4.4 outlines the socioeconomic environment at the village level. Section 4.5 describes the socioeconomic environment within the two irrigation schemes included in the study. Section 4.6 presents a summary of the chapter.

4.2 District Level

Vhembe District Municipality is in the northern part of Limpopo Province and shares borders with Capricorn and Mopani district municipalities in the east and west, respectively. The district also shares borders with Zimbabwe and Botswana in the northwest and Mozambique in the southeast through the Kruger National Park (see Figure 2). This district, which covers 27 962 148 square kilometres of land is a Category C municipality, which was established in 2000 in terms of the Local Government Municipal Structures Act No 11 of 1998. It consists of four local municipalities, namely, Thulamela, Makhado, Musina and Collins Chabane (see Figure 4). In terms of governance, the municipality consists of a mayoral executive system, which allows for the exercise of executive authority through an executive mayor in whom the executive leadership of the municipality is vested and who is assisted by a mayoral committee.

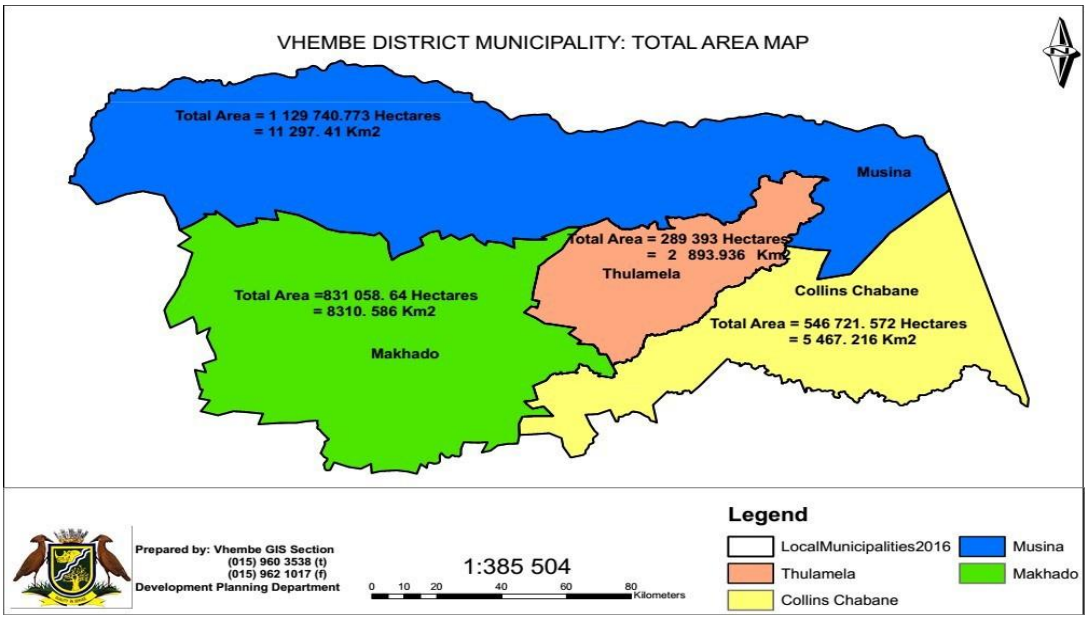

Figure 4. Municipalities within Vhembe District Municipality

Source: Vhembe District Municipality, 2020/21 IDP-Review

Ehlanzeni District Municipality is one of the three districts of Mpumalanga Province situated in the north-eastern part and covering the entire southern part of the Kruger National Park. It shares a border with Mozambique in the east and Swaziland in the south. In addition, it is adjacent to the following districts in South Africa: Sekhukhune in the north, Kangala in the west and Gert Sibande in the south (see Figure 3). EDM covers a total area of 27 895.47 km², which is about 36.47% of the total estimated land size (76 495 km²) of Mpumalanga Province (EDM IDP). The EDM consists of four local municipalities: Bushbuckridge, City of Mbombela, Nkomazi, and Thaba Chweu (Figure 4). As in VDM, the governance structure consists of a mayoral executive system.

4.2.1 Economic factors

The South African government envisioned that, in 2030, the economy should be close to full employment and that people should be equipped with the necessary skills and ensure that ownership of production is less concentrated and more diverse (where black people in general and women specifically own a significant share of productive assets). Thus, the creation of jobs and the development of skills for the people of South Africa remain the key priorities of the government (Vhembe District Municipality IDP Review, 2021/22). For these reasons, the country, through its National Development Plan, seeks to create a South African economy that is more inclusive, and dynamic, wherein the benefits of growth are shared more collectively and equitably. This suggests that the economy needs to serve all South Africans. The Provincial Development Plan is, therefore, aligned with the National Development Plan objectives.

Consequently, the Limpopo Development Plan strategy aims for annual improvement in job creation, production, income, access to public services and environmental management. These are considered as the means and instrumental in reaching the goal of development. In the same vein, VDM (like other districts in the province) has focused on the creation of jobs and poverty alleviation programmes to achieve development (Vhembe District Municipality IDP Review, 2021/22). However, the 2021/22 IDP review indicates that the district is confronted with several challenges, which include a lack of business management skills, food insecurity, a lack of market research and a lack of information about opportunities. About 556 076 people are the recipients of one form of social grants, with the largest number of recipients being the child support grants at 416 118 (Vhembe District Municipality IDP Review, 2021/22).

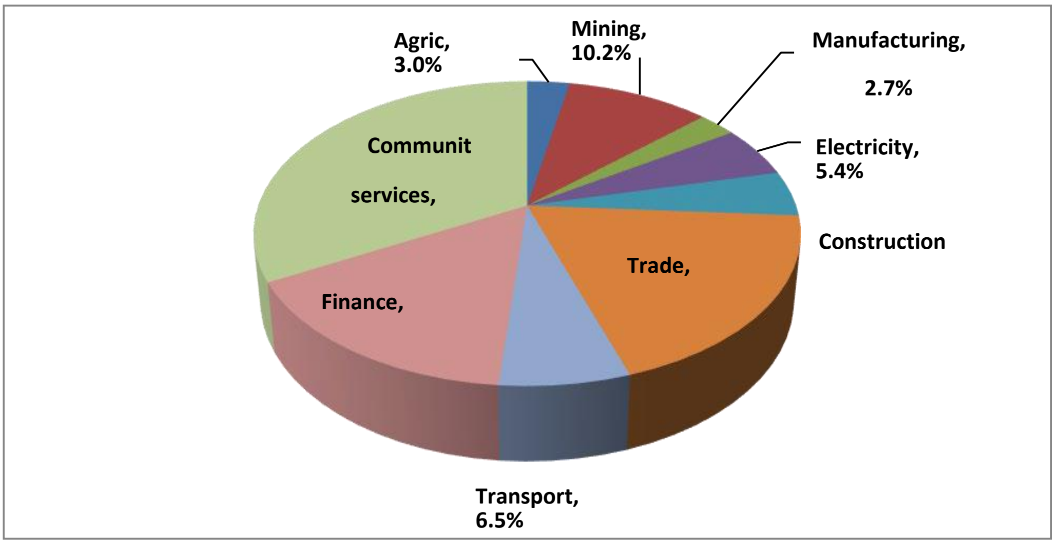

Figure 5. Employment per sector in the Vhembe District Municipality

Source: LEDET (2016) cited in Vhembe District Municipality 2020/21IDP-Review

According to Vhembe District Municipality IDP Review (2021/22), the district municipality has a total population of 1 393 949 and 38% of the population is youth. The large youth population of the district suggests that future developmental opportunities are guaranteed labour (Vhembe District Municipality IDP Review, 2021/22). Figure 6 indicates that the three economic sectors which employed the majority of the population in VDM are community services (32.9%), trade (18.8%) and finance (15.7%). The three sectors with the least contribution to employment are construction (4.8%), agriculture (3%) and manufacturing (2.7%). A majority of the population in VDM have educational qualifications and possess some skills, suggesting prospects for further growth. About 99% of the population has matric or higher qualifications (Vhembe District Municipality IDP Review, 2021/22). Despite the above, creating jobs and developing skills remain important elements for consideration by the government in the area.

According to the Ehlanzeni District Municipality Final IDP (2021/22), the Bushbuckridge Local Municipality has a total population of 1 754 931. The distribution of the population is not even across the four local municipalities in Mpumalanga. The City of Mbombela has been the fastest-growing municipality in terms of population, contributing 39.6% of the total population within the district. Regarding gender distribution, the EDM has a higher proportion of females than males in all municipalities, except in Thaba Chweu, where 52% of the population were males (Figure 7).

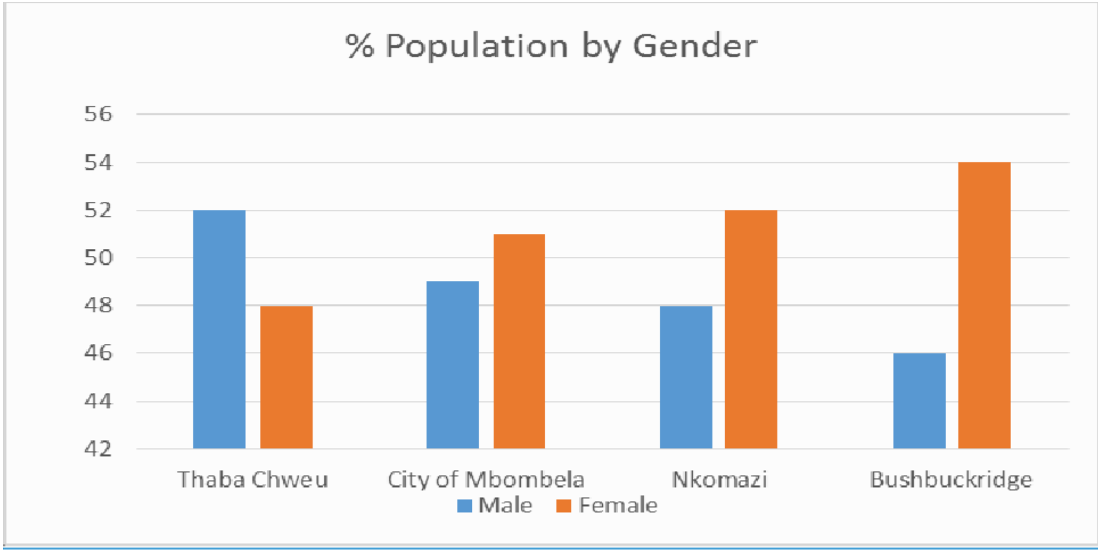

Figure 6. Population by gender in the Ehlanzeni District Municipality

Source: Statistics Community Survey (2016) cited in Ehlanzeni District Municipality 2020/21 Final IDP

Although agriculture, forestry and tourism were the main sectors in terms of land use, the main economic contributors within the EDM were trade, community and financial services. The other notable characteristic of EDM is the change in economic outlook from being agriculture-based to being industrial-based. This was driven by the link to the global economy over the past two decades (Mpumalanga Treasury, 2015). According to Ehlanzeni District Municipality Final IDP (2020/21), major industrial centres are Mbombela, White River and Ntsikazi.

4.2.2 Social factors

The VDM has a total of six functional district hospitals, one regional hospital, one specialised hospital, 115 clinics, eight community health care centres and 19 mobile clinics. Furthermore, primary health care facilities are providing comprehensive primary health care package to the population in the area. Despite these health facilities, there are challenges such as a shortage of professional and support staff, high levels of crime, and poor roads to access some of the health facilities. Norms and standards prescribe that, a school needs to be within a radius of 5 km from the community it serves and the total walking distance to and from school may not exceed 10 km.

The VDM comprises 938 public schools in total and many of these schools are in Thulamela and Makhado, given their population concentration (Vhembe District Municipality IDP Review, 2021/22). However, a majority of the rural schools within the VDM do not meet the norms and standards of education infrastructure as they lack some of the important infrastructure such as sports fields, halls, and laboratories. In addition, some of the infrastructure does not meet the health and safety norms and standards as they consist of inappropriate or poor sanitation facilities. Notable is that all schools in the area have access to some form of sanitation and most have perimeter fencing (Vhembe District Municipality IDP Review, 2021/22).

4.3 Local Level

In terms of the Local Government Structures Act number 117 of 1998, Thulamela Local Municipality (TLM), which is one of the four local municipalities in Vhembe District Municipality, is a category B municipality. TLM is the smallest of the four municipalities, covering an area of 2 893.963 square kilometres, which is mainly tribal land. Thohoyandou is its political, administrative, and commercial centre (Louw and Flandorp, 2017; Thulamela Municipality IDP 2020/21-2022/23). The municipality shares boundaries with Collins Chabane Municipality in the southeast, Musina Municipality in the northeast and Makhado in the west (Thulamela Municipality IDP 2020/21-2022/23). Whilst it is a known fact that Limpopo Province is the driest, poorest and least urbanised (i.e. 11% urbanised) province in South Africa (Statistics South Africa, 2011; Machethe et al., 2004; Louw and Flandorp, 2017), TLM registered an urbanisation level of 14.6%. Although this is higher than the figures for the province and Vhembe District (i.e. 13.8%), it also signifies the predominantly rural character of the municipal area, with the major pockets of rural-urban concentration in and around its administrative centre, Thohoyandou (Louw and Flandorp, 2017).

Regarding population size, based on the demarcation changes and community services in 2016, TLM still carries the largest population of all municipalities within Limpopo Province with a total of 497 237, comprising 269 398 females and 227 839 males as indicated in Tables 5 and 6. However, the population distribution is spatially uneven, with high concentrations around Thohoyandou (Louw and Flandorp, 2017). Like other municipalities, TLM has more females than males.

Machethe et al. (2004) indicated that women are in the majority in irrigated smallholder agriculture but their participation in decision-making has been limited. Van Koppen et al. (2017) also reiterated that, even where women are in the minority when it comes to official membership within irrigation schemes, they are mainly the ones cultivating the land within the irrigation schemes. The same authors also noted that the exclusion of women from collective irrigation decision-making may be attributed to women being in second position after men when it comes to formal membership registrations within most irrigation schemes (Van Koppen et al., 2017). Also, women have long been considered in how the goals of development, population control and environmental sustainability can be realised (Jiggins, 1994), suggesting that they should be accounted for as role players in rural development. Furthermore, the predominance of female households in TLM is due to the absence of men employed or in search of employment opportunities outside the region mmm (Louw and Flandorp, 2017).

Table 5. Population size based on revised boundaries and percentage change

Municipalities	1996	2001	% Change	2011	% Change	2016
Vhembe	1 095 728	1 197 952	1.8	1 294 722	0.8	1 393 948
Thulamela	533 757	581 487	1.7	618 462	0.6	497 237
Musina	33 061	39 310	3.5	68 359	5.5	132 009
Makhado	445 597	494 264	1.6	516 031	0.4	416 728
Collins Chabane	-	-	-	-	-	347 974

Source: Louw and Flandorp (2017); Thulamela Municipality IDP 2020/21-2022/23

Table 6. Population size in 2016 based on revised boundaries by gender composition

District Municipality/Local Municipality	Population (Male)	Population (Female)	Total Population
Vhembe	**643 758**	**750 191**	**1 393 949**
Musina	65 856	66 153	132 009
Thulamela	227 839	269 398	497 237
Makhado	195 012	221 398	416 728
New	155 051	192 924	347 975

Source: Louw and Flandorp (2017)

Table 7. Annual growth rate in Bushbuckridge Local Municipality

Local municipal area	Population		Average population annual growth	Projected 2030 number
	2011	2016	2011-2016	
Bushbuckridge	541 248	548 760	0.3%	572 263
Mpumalanga	4 039 939	4 335 964	1.6%	5 533 629

Source: StatsSA (2011)

Regarding population size in BLM, the population grew from 541 248 in 2011 to 548 760 in 2016, which is a growth rate of 0.3% (Table 7). This growth rate is lower than the population growth rate of 1.6% for Mpumalanga Province.

4.3.1 Economic factors

Education plays an important role within society since it determines the level of understanding, planning and reasoning of the people. A total of 95 654 people within Thulamela Municipality are social grant recipients (Thulamela Municipality IDP 2020/21-2022/23). This relatively high dependence on social grants is indicative of a lack of better employment opportunities as the estimated unofficial unemployment rate within the municipality was once 43.8% (Louw and Flandorp, 2017). Agriculture, hunting, forestry and fishing, which contributed only 3.3% to employment within the municipal area, have a great potential in raising the level of employment. Furthermore, the fact that the population in TLM trends towards a young age structure (Thulamela Municipality IDP 2020/21-2022/23) presents an opportunity for the growing men and women to participate in economic activities such as agricultural projects. TLM is said to have a huge agricultural potential and complementary resources to make a significant contribution towards the National Development Plan 2030 (Louw and Flandorp, 2017).

The Bushbuckridge Local Municipality has poor road infrastructure, limited water supply, and poor service delivery (Bushbuckridge Local Municipality, 2020). All the above factors limit agricultural development because they increase the cost of production and result in the market being inaccessible to farmers. The municipality does not have an economic hub where farmers can have access to the formal market, which forces them to rely on the informal market for sales. In addition, Agholor and Nkosi (2020) identified financial constraints, inadequate knowledge of water conservation practices, government policies, and a lack of water technical guidelines as factors leading to smallholder farmers' inability to adopt sustainable water use practices.

According to the Bushbuckridge Local Municipality Final IDP (2020/21), there was an increase in poverty levels from 56.8% to 63.5% from 2014 to 2017. This is attributed to the government being the main employer in the municipality, which is unsustainable in the long run. On a positive note, the BLM saw an unemployment rate decrease from 52.1% in 2011 to 46.4% in 2015. Nonetheless, BLM is the municipality with the second highest unemployment rate in Mpumalanga after Nkomazi Municipality. Considering the nature of the municipality, employment opportunities remain negligible. The majority of the people in BLM also depend on social grants. Child support and old age grants are dominating with 209 055 (77%) and 41 584 (15%) recipients, respectively (Bushbuckridge Local Municipality Final IDP, 2020/2021).

4.3.2 Social factors

In South Africa, spatial development decisions and investment priorities are guided by the principles contained in the National Spatial Development Perspective. TLM has access to a wide range of community services, which include health, education, libraries, and safety and security. Regarding the type of dwellings, out of the total households of 130 321 in TLM, the dominant types of dwellings were formal dwellings/houses or brick/concrete block structures (112 181) and traditional dwellings/hut/structures (6 754) made of traditional matter. Informal dwellings/shacks (both in the backyard and not in back yard) were 4 414 (2 524 +1 890) (see Thulamela

Municipality IDP 2020/21-2022/23, p 20-21 for all-inclusive detailed dwellings).

As regards land ownership, TLM is characterised by private ownership such as freehold title and state-owned land (i.e. leasehold/PTO) by COGHSTA, Municipal and Department of Rural and Land Reform. Agriculture remains the main source of rural development in TLM. However, according to Louw and Flandorp (2017), the current land tenure system (communal land rights) combined with strained communication between traditional leaders, the municipalities, and other relevant stakeholders, are posing considerable challenges that hinder development within this sector. The land tenure status by type of tenure and area occupied is presented in Table 8.

Table 8. Land tenure status in Thulamela Municipality

Tenure status	Area of occupation (ha)
Rent	8 251
Owned but not paid off	6 630
Occupied	38 479
Owned and Fully Paid	102 522
Other	712
Total	**156 594**

Source: BLM's IDP (2020/2021)

According to the Bushbuckridge Local Municipality's Final IDP (2020/2021), the provision of higher education remains a challenge at municipal level due to the lack of proper higher education facilities in the province. A high failure rate is prevalent in many schools, which explains why only 17% of the people in the municipality have matric. The municipality is characterised by poor infrastructure and facilities and overcrowding in schools. This negatively affects the quality of education and slows the process of technology adoption and agricultural development. In support, Agholor and Nkosi (2020) indicated that farmers with a higher level of education are more likely to adopt water conservation practices because they have better knowledge about the importance of efficient water use.

4.4 Village Level

Local municipalities are implementing rural development programmes within the villages. Therefore, assessing the socio-economic environment within a village may shed light on important and relevant issues of concerns that need to be addressed. Malavuwe village, where Matsika irrigation scheme is located, is in Ward 39 of the TLM in Vhembe District Municipality. This village is about 26 km northeast of Thohoyandou. The village falls within the chieftainship of Chief Mphaphuli. There are about 1 200 households in the village (Musiwalo, 2013). The area, just like many areas in rural South Africa, is characterised by underdevelopment, poverty, and unemployment. Numerous rural development projects (e.g. RDP and EPWP) were implemented in the area with the purpose of advancing the livelihood of the communities. Despite this, unemployment remains a challenge. For instance, whilst EPWP projects are known to create jobs for community members across the villages, in many instances, the employment is temporary. Hence, permanent sustainable jobs would be more beneficial in the longer term and agricultural projects have great prospects for improving food security and creating employment in the medium to long term.

New Forest Village is in Ward 10 in the Bushbuckridge Local Municipality in Mpumalanga Province. It is a small rural area that has a population of about 5 913. As regards governance, this village is ruled by Chief Nxumalo (Mnisi, 2011). Many households in New Forest own a variety of domestic, agricultural, and electronic assets. According to Ncube (2018), some of the agricultural assets owned by these households include ploughs, tractors, wheelbarrows, knapsack sprayers, donkey carts and other garden tools (spades, forks, hoe).

4.4.1 Social factors

Various rural development programmes have been implemented in Malavuwe Village aimed at improving the socio-economic status of the local people. Specific Expanded Public Works Programme (EPWP) projects that have been implemented in the village include the Malavuwe Health Centre, Malavuwe tarred road and Malavuwe River Bridge (Musiwalo, 2013). These projects have created employment for the local people. For example, the construction of Malavuwe tarred road and Mutshindudi River Bridge as part of EPWP not only brought hope by providing employment to the residents of Malavuwe Village, but they have also made the village accessible (Musiwalo, 2013). Good roads between farms, towns and cities are important as they shorten the distance and travel time for farmers (Louw and Flandorp, 2017). They also enable farmers to mainstream into the economy by transforming their farming into businesses and not just subsistence activities.

Notwithstanding the availability of these infrastructures and the great benefit they provide to the residents of Malavuwe Village and their surrounding villagers, the poor quality of the tarred road remained a concern for the residents. Another developmental project implemented in Malavuwe that played a big role in the study area includes the building of RDP houses. The Malavuwe community also benefited from the sponsorship of the National Development Agency in collaboration with the Department of Health and Social Welfare. The sponsorship made it possible for the community to have a multi-purpose centre, with classrooms for pre-scholars, and a community hall. The community hall is used for meetings, and functions and as a home for orphans and vulnerable children.

In New Forest, there is a high unemployment rate and the majority of the unemployed are women (Ncube, 2017). Moreover, the community's involvement in the water project and decision-making is limited, which has a negative impact on water and sanitation service delivery. A lack of access to information and involvement, therefore, disables the community from being part of the change and affects their ability to participate in sustainable water use practices.

4.4.2 Economic factors

Apart from the sponsored projects, there are a number of self-sustaining projects within the Malavuwe Village, which contribute to employment creation and profit generation. These provide livelihoods for the residents and capacitate them with various skills, such as farming and sewing. Apart from the Matsika irrigation scheme under consideration in this research, there are other projects such as Malavuwe Community Bakery Project, Malavuwe Community Sewing Project, Malavuwe Mesh Wire Project, and Malavuwe Piggery Project Malavuwe Poultry Project as well as Malavuwe Irrigation Scheme. These were all sponsored by the National Development Agency in collaboration with other stakeholders, such as the Department of Agriculture. The role of self-sustaining projects cannot be overemphasised, especially in a country like South Africa where the triple challenge of poverty, unemployment and inequality is a reality for the majority of the citizens. There is no doubt that such projects play a significant role in rural development and capacity building.

A study by Ncube (2018) determined the impact of irrigation schemes on the livelihoods of socially differentiated smallholder farmers in New Forest. The study revealed that the households in the New Forest Irrigation Scheme own agricultural assets such as tractors, wheelbarrows, and ploughs. Moreover, these farmers rely on numerous income sources, which include social grants, irrigation farming, and formal and piece jobs. However, at least 95% of farmers rely on irrigation farming income and only a few of them have jobs. Hence, formal employment does not play a significant role in the livelihoods of households in New Forest.

Most villages have limited access to water and sanitation facilities, which is exacerbated by the privatisation of these services. Moreover, the privatisation of water rights renders water inaccessible due to the high unemployment rate in rural areas. Infrastructure failure also leads to poor water and sanitation coverage (Mnisi, 2011). This is supported by Raab et al. (2008), who indicated that water and sanitation challenges are due to historic underdevelopment of the BLM. Ncube (2017) indicated that water and sanitation supply is below RDP standards in New Forest since most households are still using pit latrines. According to Ncube (2017), the current water supply does not meet water demand and the communal water pumps experience regular water cuts.

The current electric water pump is small and cannot cater to the whole community. A study by Mnisi (2011) determined the causes of water shortage in New Forest and assessed water and sanitation infrastructure in the village. The results of the study revealed that socio-economic status plays a huge role in service delivery and poor people are more likely to be deprived of these services due to the privatization of water, electricity, and sanitation services.

4.5 Irrigation Scheme Level

4.5.1 Irrigation system

The two irrigation schemes use different in-field water application methods. Matsika irrigation scheme uses micro-jet technology while New Forest uses canal/flood irrigation, relying on water from the river and dams using gravity. Respondents at Matsika indicated that they initially had sprinklers, which never worked. They are using micro-jet because they reckon it is ideal as it irrigates both crops, composting and mulching.

4.5.2 Infrastructure

Whilst the site visit and initial conversations with the scheme representatives indicated the existence of some good infrastructure and movable assets for the schemes under investigation, the results also highlighted the conditions of dilapidated infrastructure.

At New Forest, during the first visit in April 2021, it was noted that sections of the irrigation canals were vandalised/damaged, leading to insufficient irrigation water (Figures 7 and 8). The follow-up discussion in December 2021 with one of the officials working at New Forest irrigation scheme indicated that some of the main canals within the scheme were fixed. Furthermore, the follow-up discussion confirmed that the scheme draws water from the river and 11 dams, relying on gravity (i.e. independent of any pumps).

During the field visit to New Forest irrigation scheme, it was indicated that there is a dire need for movable assets such as tractors. In the past, the Department of Agriculture provided tractors during ploughing season however, this support is no longer available. Farmers have to rely on independent contractors for ploughing services. These tractors are few rendering it difficult for farmers to have the fields prepared timeously, especially during the peak periods of the planting season.

At Matsika irrigation scheme, movable assets include a truck, a tractor and a forklift (see Figure 9). The building infrastructure includes a pack house for grading bananas, with two big refrigerators and a conveyor belt, a kitchen, an office with office furniture, two toilets, storeroom and a reception area (see Figure 10).

During the first field visit in April 2021, it was indicated that the three water pumps at their disposal were damaged by rainwater (one of the pumps was later repaired). This caused irrigation water to be slower than expected and affected productivity levels. However, during a follow-up visit in December 2021, it was indicated that the three pumps were not working. This meant that there was limited to almost no production as it was impossible to irrigate, and farmers had to rely on rainfall. The farmers were not fixing the pumps at that stage because of a lack of funds.

Figure 7. Major challenges with canals at New Forest irrigation scheme
Source: Fieldwork 2021

Figure 8. Major challenges with unmaintained/damaged canals at New Forest irrigation scheme

Source: Fieldwork 2021

Figure 9. Some movable infrastructures available at Matsika irrigation scheme
Source: Fieldwork 2021

Figure 10. Some building infrastructures (pack *house, office, refrigerators, and conveyor belt)* available at Matsika irrigation scheme

Source: Fieldwork 2021

4.5.3 Input and output markets

At Matsika irrigation scheme, farmers purchase inputs such as irrigation pipes from Water 2000 at Makhado and Levubu and irrigation repairs tools at Thohoyandou. Seedlings for the bananas were previously provided by the Department of Agriculture and Rural Development. Farmers' representatives indicated that, even technical inputs, such as fertilizers (Ilima programme) were also provided by the department. However, during the data collection this was no longer the case and farmers were not applying fertilizer. This revealed that the project was not self-sustaining. The farmers noted that they sell their produce to the local communities and traders coming directly to buy from the project. The low quality of bananas produced could explain why their sales are local (see Figure 11).

Figure 11. Banana crops, indicating low quality bananas due to insufficient irrigation at Matsika irrigation scheme

Source: Fieldwork 2021

At New Forest irrigation scheme farmers purchase inputs such as fertilizers and agro-chemicals from Hazyview Cooperative and Hoedspruit Obaro, which are 80-90 km from the scheme. Seedlings were largely purchased from White River Nursery, which is about 120 km from the scheme. Farmers do not have a formally organised market for their produce and, therefore, rely on local markets (local communities and nearby supermarkets). The farmers took pride in sharing that in a good season, they can attract buyers from far afield. They attributed this to the quality of their produce.

4.5.4 Existing organisations

Matsika irrigation scheme is organised as a cooperative. Almost all the beneficiaries of the project are also members of Thusalushaka Agricultural Cooperative. The role of the cooperative is to provide leadership and governance role as well as services and technical assistance to the beneficiaries/farmers. The scheme has a dedicated government extension officer.

At New Forest irrigation scheme, the cooperative is not functional due to multiple challenges that farmers are facing, including conflicts and disagreements among scheme members. In the main, there seems to be mistrust between the management committee and the general members, especially as concerns sharing of disaster relief packages and related farmer support that the government makes available to the scheme.

4.5.5 Government departments operating in the area and their role

The farmers at Matsika indicated they largely received support from the Departments of Agriculture and Rural Development and Land Reform. Support was provided as follows: CASP provided funding for infrastructure and the building (office and pack house). The Department of Agriculture and Rural Development provided funding for movable assets (tractors, a forklift, a truck and a bakkie). The department also provides advisory services on various aspects. The level of commitment from officials of the department is pronounced and regular interaction appears to be the norm. However, the question that remains is whether the needs of the farmers are addressed during these visits/sessions. This question will be addressed in the next stage of the research project.

At New Forest irrigation scheme, farmers receive support from the Departments of Agriculture and Rural Development and Land Reform. The Department of Agriculture provides farmer support services through the existing programmes. The Department of Rural Development and Land Reform provides support in terms of infrastructure maintenance. Private entities provide mechanisation support at a high cost to the farmers.

4.5.6 Concerns/issues raised by farmers

Both farmers and Department of Agriculture officials working at the irrigation scheme noted that irrigation water was insufficient due to the damaged water pumps. This is threatening the sustainability of the scheme, if left unattended.

The farmers also noted that, in 2019, some money (i.e. R207 000) went missing and the funds have not yet been recovered. Another R32 000 also went missing during a robbery on the way to the bank. Both officials and farmers reckon that proper financial management (which may require further intervention and training) and transparency in communication can address some of these challenges.

Farmers further noted that service providers who were contracted by the Department of Agriculture as mentors to the farmers had minimal understanding of their work. They indicated that the mentors took the money and disappeared. The mentorship was intended to assist farmers with planting, farming operations and marketing during 2016-2018.

There is a view that certain commodity groups could be favoured over others (such as bananas and citrus), whereas commodities such as mangos, macadamias and irrigated vegetables receive less attention from government officials. There is a need to determine whether the progress made to date is attributable to adequate and consistent extension services received as well as the funding and other support (mentorship/strategic partnership) received from the government.

During the field visit in December 2021, we learnt that a few weeks prior to our visit, about seven kilometres of field of bananas burnt down. The first enquiry as to what caused the fire indicated that it was due to negligence by someone who accidentally dropped a cigarette on the ground. However, some respondents suspect that internal politics may have played a role and that the fire may not have been an accident. Instead, they believe it may have been caused by farmers who may be seeking compensation from the Department of Agriculture's Disaster Management Fund.

Government officials also noted that some of the farmers want to lease their farm as they argue that they are unable to run the scheme successfully. Their idea is to lease their farm so that other farmers or service providers can use it and pay rent to the land owners. In relation to this point, the December 2021 field visit coincided with a meeting between a private company and the farmers to discuss the possibility of a strategic partnership. The meeting was followed by an inspection of the project to assess the current situation of the project and the existing infrastructure (see Figure 12).

Figure 12. Infrastructure and banana field observations after a meeting between Crooks Brothers Company and Thusalusaka Agricultural Cooperative committee members
Source: Fieldwork 2021

A study (Ncube, 2018) conducted in the area noted the inadequate supply of water for irrigation owing to damaged and broken infrastructure. This was also observed by the research team during the April 2021 site visit (see Figures 7 and 8). According to Ncube (2018), the problem of insufficient water worsens during the dry season.

The cooperative is not functional due to conflicts among the farmers. This was raised as a serious concern because the cooperative was providing essential services. Therefore, it will be important to investigate this issue further.

During the follow-up discussion in December 2021, when asked about the existence of any strategic partnerships between the farmers and other private actors (with or without the support of government), officials working in the area indicated that these were non-existent for small-scale farmers. However, they were available for large commercial farmers.

4.6 Summary

The purpose of Chapter 4 was to assess the socioeconomic environment within which smallholder farmers operate. This is important as the socioeconomic environment affects what happens on the irrigation scheme, including decisions on the adoption of technology. The assessment was done at different levels (irrigation scheme, village, local and district municipality) for the two irrigation schemes (Matsika and New Forest).

Poor infrastructure and the provision of quality education are serious problems in the two district municipalities of Vhembe and Ehlanzeni. For instance, in Vhembe District Municipality, a majority of the rural schools do not meet the norms and standards of educational infrastructure. Ehlanzeni District Municipality also suffers the same fate and only less than a quarter of the population has a matric qualification. Illiteracy is, therefore, a barrier to agricultural development because it can lead to a low adoption rate of new and improved technologies. Poor infrastructure makes it difficult for farmers to transport their produce to the market and inputs to their farms.

A majority of the people in the two local municipalities (Thulamela and Bushbuckridge) depend on social grants due to a lack of adequate employment opportunities. Therefore, there is a potential for agriculture to make a significant contribution to livelihoods by providing employment. This is especially so for Thulamela Local Municipality, which has a huge agricultural potential and complimentary resources to make a significant contribution to the National Development Plan 2030. Although agriculture is considered as a key to rural development in Bushbuckridge Local Municipality, agricultural development will be limited by water shortage. The available underground water is in short supply and, therefore, this will affect the expansion of irrigation. In this regard, good water use management strategies are required to ensure that the available water is enough for both irrigation and domestic use. Furthermore, the existence of a younger population in both municipalities presents an opportunity to participate in economic activities, such as agricultural projects, provided they are properly skilled and have relevant experience.

Both Malavuwe and New Forest villages exhibit some level of underdevelopment, characterised by high levels of poverty and unemployment. Notwithstanding the various developmental projects that have been implemented in these villages, there is room for improvement, especially in terms of permanent and sustainable employment creation. Therefore, based on the socioeconomic standing of these two villages, including the available resources, skills and infrastructure, sectors such as agriculture can be further developed to improve the livelihoods of the communities. Ensuring that irrigation schemes perform optimally will go a long way in advancing the contribution of agriculture to poverty reduction and employment creation. The majority of farmers in New Forest rely on the irrigation scheme for income. However, their involvement in the decision-making process of the irrigation scheme is limited. This will have a negative impact on the development of the scheme as it leads to communication breakdown. It could also affect the effectiveness of the project since the decisions affecting the scheme may not necessarily respond to farmers' problems and needs.

CHAPTER 5: ADOPTION OF IRRIGATION WATER-EFFICIENT TECHNOLOGIES

5.1 Introduction

This chapter is about the adoption of water-efficient irrigation technologies in New Forest and Matsika irrigation schemes. The proportions of farmers that have adopted the different irrigation and crop technologies are presented. The chapter also considers the farmers' familiarity with and knowledge of the various irrigation technologies and their perceived efficiency of water use. The issue of whether farmers would like to change the existing irrigation system is also discussed. The chapter also covers the issue of the frequency of maintenance of irrigation infrastructure.

Subsequent sections of the chapter are organised as follows: Section 5.2 discusses the crop irrigation technologies used in the two irrigation schemes. Irrigation technologies used in the two irrigation schemes are described in Section 5.3. Section 5.4 summarises the chapter.

5.2 Crop production Practices and Technologies

Crop production practices/technologies can have a significant effect on irrigation water use efficiency. Therefore, it was deemed necessary to establish what cropping practices smallholder farmers were using in the two irrigation schemes. Farmers were requested to indicate whether they were using or applying certain farming practices, including no-tillage cultivation, soil mulching, use of drought-tolerant and improved seed varieties, rainwater harvesting and chemical fertiliser application. The number and proportion of smallholder farmers using or applying these practices/inputs are indicated in Table 9.

Table 9. Crop production technologies used in small-scale irrigation schemes in Limpopo and Mpumalanga provinces (n= 104)

Crop production Technology	**No. of respondents**		**Percentage**	
	New Forest	*Matsika*	*New Forest*	*Matsika*
Practise no-tillage	48	31	80.0	70.5
Practise soil mulching	33	35	55.0	79.5
Practise water harvesting	25	41	41.7	93.2
Use drought-tolerant seed	40	37	66.7	84.1
Use improved seed	50	34	83.3	77.3
Use chemical fertiliser	55	32	91.7	72.7
Practise site-specific nutrient application	50	21	83.3	47.7

Source: Field Survey (2022)

In both irrigation schemes, between 67% and 84% of the farmers were using drought-tolerant seeds, improved seed, and chemical fertiliser. The proportions of farmers practising no-tillage cultivation for Matsika and New Forest were 71% and 80%, respectively. Sithole et al. (2016) advocate for this practice and posit that it directly affect soil physical properties by increasing residue retention, and decreasing soil disturbance and Carbon loss which are essential for plant structure and growth. Water harvesting is practised by most farmers in Matsika (93%). New Forest irrigation scheme has a lower proportion (42%) of farmers practising water harvesting. Soil mulching is popular in Matsika as about 80% of the farmers indicated that they were practising it while only 55% were doing so in New Forest. The possible reason for this technology's popularity can be attributed to its ability to reduce water usage, and boost soil temperature and weeds suppression (El-Beltagi et al., 2022). With regards site-specific nutrient application, only 48% of the farmers in Matsika indicated that they were practising it while the proportion for New Forest was 83%.

5.3 Irrigation Technologies

Farmers were asked about the different types of irrigation technologies/systems to gauge their knowledge about them. The responses of farmers are presented in Table 10.

Table 10. Knowledge of irrigation technologies in small-scale irrigation schemes in Limpopo and Mpumalanga provinces (n=104)

Irrigation technology	**No. of respondents**		**Percentage**		**Cumulative %**	
	New Forest	Matsika	*New Forest*	Matsika	*New Forest*	Matsika
Flood/furrow	19	-	31.7	-	31.7	-
Drip	-	1	-	2.3		2.3
Sprinkler	-	6	-	13.6		15.9
Flood and micro	-	2	-	4.5		20.4
Drip and flood	4	-	6.7	-	38.4	-
Drip and sprinkler	-	6	-	13.6		34.0
Drip, flood and micro	-	1	-	2.3		36.3
Sprinkler and micro	-	2	-	4.5		40.8
Drip, flood and sprinkler	17	9	28.3	20.5	66.7	61.3
Flood, sprinkler and micro	8	-	13.3	-	80.0	-
All	12	17	20.0	38.6	-	-
Total	**60**	**44**	**100**	**100**		

Source: Field Survey (2022)

On average, about 29% of the farmers knew about all four different types of irrigation technologies/systems (i.e. drip, flood, sprinkler and micro). The proportion of farmers who indicated they knew about flood, drip and sprinkler irrigation was about 25%. In a study by Mkuna and Wale (2023) in KwaZulu-Natal, they found that bucket, flood, and sprinkler irrigation were the three common irrigation types found in and around the four irrigation schemes. To establish whether farmers were aware of the performance of the different irrigation technologies in terms of irrigation efficiency, they were requested to indicate the technologies they considered to be efficient in water use. The results are presented in Table 11.

Table 11. Farmers' perceptions of irrigation efficient technologies in small-scale irrigation schemes in Limpopo and Mpumalanga provinces (n=104)

Irrigation technology	No. of respondents		Percentage		Cumulative %	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*New Forest*	*Matsika*
Drip	36	17	60	38.6	60.0	38.6
Flood/furrow	14	1	23.3	2.3	83.3	40.9
Sprinkler	7	19	11.7	43.2	95.0	84.1
Micro	-	5	-	11.4		95.5
Drip and sprinkler	1	1	1.7	2.3	96.7	97.8
Drip and micro	1	1	1.7	2.3	98.4	100
All	1	-	1.7	-	100	
Total	**60**	**44**	**100**	**100**		

Source: Field Survey (2022)

Drip irrigation was considered as the most efficient by 49% of the farmers. Surprisingly, flood irrigation was rated as the most efficient irrigation technology by 12% of the farmers. About 28% of the farmers considered sprinkler irrigation to be the most efficient technology. Micro irrigation was considered as the most efficient technology by only 5% of the farmers. Mkuna and Wale (2023) concur with these findings that farmers use an irrigation system/technology based on the mechanics they have available and their perception of maximum utility not necessarily on efficiency.

On average, 47% of the farmers would like the existing irrigation system to be replaced (see Table 12). The proportion of farmers who would like the existing irrigation system to be replaced was 62% for New Forest and 32% for Matsika. The high proportion of farmers who would like the existing irrigation system to be replaced in New Forest is an indication of the problems and inefficiencies associated with flood irrigation. Mutambara et al. (2014) reached a similar conclusion in Zimbabwe and posited that the poor performance of many irrigation schemes can be attributed to the rapid deterioration of the irrigation infrastructure. These require recurrent investments for rehabilitation.

Table 12. Desire to replace existing irrigation technology in small-scale irrigation schemes in Matsika and New Forest irrigation schemes (n=104)

	New Forest		**Matsika**	
	Number	%	Number	%
Replace irrigation technology	37	61.7	14	31.8
Satisfied with existing technology	23	38.3	22	50.0
Unknown	-	-	8	18.2
Total	**60**	**100**	**44**	**100**

Source: Field Survey (2022)

Almost all the farmers in the two irrigation schemes practise irrigation scheduling. The proportions of farmers practising irrigation scheduling are 88% in New Forest and 86% in Matsika (see Table 13), although the irrigation scheduling was mostly reliant on water availability and arrangements between the farmers in the irrigation scheme and community members.

Table 13. Practising of irrigation scheduling in small-scale irrigation schemes in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Number	%	Number	%
Practise scheduling	53	88.3	38	86.4
Do not practise scheduling	7	11.7	6	13.6
Total	**60**	**100**		**100**

Source: Field Survey (2022)

Table 14. Frequency of irrigation system maintenance in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		Percentage		Cumulative %	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*New Forest*	*Matsika*
Never	6	1	10.0	2.3	10.0	2.3
As per need	44	36	73.3	81.8	83.3	84.1
Every 6 months	3		5.0	-	88.3	
Annually	2		3.3	-	91.7	
Other	5	6	8.3	13.6	100	97.7
Unknown		1		2.3		100
Total	**60**		**100**	**100**		

Source: Field Survey (2022)

Regular maintenance of the irrigation system is essential to avoid unnecessary loss of irrigation water. Despite this, 77% of the farmers in the two irrigation schemes indicated that irrigation system maintenance was only undertaken when needed (see Table 14). On average, 6% of the farmers indicated that irrigation system maintenance was never undertaken. Namara et al. (2011) also found that the lack of repair of the irrigation infrastructure in Ghana severely contributed to low yield returns in many irrigation schemes.

5.3 Summary

Chapter 5 is about the adoption of irrigation water-efficient technologies among farmers in Matsika and New Forest irrigation schemes. The results show that at least 67% of the farmers in the two irrigation schemes are using improved seed, drought-tolerant seed varieties, and chemical fertilisers. With regards irrigation technologies, only 29% of the farmers in the two schemes are familiar with all four types of irrigation systems (i.e. flood, drip, micro and sprinkler).

In terms of irrigation water efficiency, drip irrigation was considered as the most efficient by 49% of the farmers. About 12% of the farmers considered flood irrigation as the most efficient whilst 28% of the farmers believed that sprinkler irrigation was the most efficient. Only 5% of the farmers rated micro irrigation as the most efficient. At least 86% of the farmers practise irrigation scheduling.

A significant proportion of the farmers in the two irrigation schemes would like the existing irrigation system to be replaced with more efficient irrigation systems but they do not have the means to effect the change. Most of these farmers are from New Forest. About 77% of the farmers in the two irrigation schemes stated that maintenance of the irrigation system was undertaken only when needed. This is concerning as irrigation systems require regular maintenance to operate optimally.

CHAPTER 6: FACTORS AFFECTING ADOPTION OF IRRIGATION WATER EFFICIENT TECHNOLOGIES

6.1 Introduction

This chapter presents the results of the study on barriers to the uptake of irrigation water-efficient technologies in the two irrigation schemes. The results were derived from the responses of farmers to specific questions asked to determine what prevented them from using irrigation water-efficient technologies. The results are divided into four sections, namely, irrigation technologies/systems, crop production practices/technologies, the role of change agents, farmers' perspectives on factors inhibiting technology adoption, and the socio-economic environment.

Subsequent sections of the chapter are organised as follows: Section 6.2 discusses the barriers to the adoption of irrigation technologies/systems. This is followed by Section 6.3 which provides explanations for farmers to not adopt crop production practices that would lead to the efficient use of irrigation water. Section 6.4 discusses barriers to technology from the perspective of the farmers. The socio-economic environment within which farmers operate as a barrier to technology adoption is discussed in Section 6.5. A summary of the chapter is presented in Section 6.6.

6.2 Irrigation Technologies (irrigation systems)

Chapter 5 confirmed that most (62%) farmers at New Forest would like the current flood/furrow irrigation system replaced with a more water-efficient system such as drip, micro or sprinkler. However, they lack the resources to effect the change. At Matsika, about 32% of the farmers indicated that they would like the current micro irrigation system replaced. We can conclude from the responses of the farmers that the main barrier to the adoption of a new irrigation system where farmers prefer to replace the existing one, is the lack of funding.

6.3 Crop Production Practices (technologies)

6.3.1 No-tillage cultivation

No-tillage farming, also known as zero tillage or direct seeding, is a practice where the soil is left undisturbed or minimally disturbed during the planting process. This practice preserves the soil's natural structure and composition by leaving it undisturbed. The preceding crop's residues are often kept on the surface as a protective layer because they add organic matter, prevent erosion, and help the soil retain moisture.

Table 15 shows that the proportions of farmers practising no-tillage (not applicable) were 73% and 80% for Matsika and New Forest, respectively. Overall, 77% of the farmers indicated that they were practising no-tillage. As indicated earlier, there are several reasons why farmers adopt practices, when it comes to no tillage, a study by Osewe et al. (2020) reasoned that minimum tillage practice provided farmers with food security in the case of unpredictable rainfall. Myeni et al. (2019) support this assertion.

Table 15. Why farmers are not practising no-tillage cultivation in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		**Percentage**		**Total**	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Not applicable	48	32	80.0	72.7	80	76.9
Using tractor	8	3	13.3	6.8	11	10.6
No information	1	4	1.7	9.1	5	4.8
Encourages weeds	-	1	-	2.3	1	1.0
Costly	-	1	-	2.3	1	1.0
Time consuming	0	1	-	2.3	1	1.0
Not good for crops	-	1	-	2.3	1	1.0
Not comfortable	-	-	-		-	-
Missing information	3	1	5.0	2.3	4	3.8
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

Of the remaining 24 of the farmers, 67% (16) indicated that they were not practising no-tillage due to their preference for using tractors to plough and a lack of information about the practice. Other reasons provided for not using no-tillage included the following: it is time-consuming, encourages weed growth, is not good for crops and is costly. To add to this, a study by Tadjiev et al. (2023) found that the lack of access to new technologies and knowledge about conservation tillage practices limits the wider adoption of zero tillage among smallholders in Kyrgyzstan.

6.3.2 Mulching

According to Ahmad et al. (2015), mulching also plays an important role in weed suppression and, therefore, reducing competition for nutrients, light and water between the crop and weeds. Table 16 presents information on the reasons why farmers were not using mulching in Matsika and New Forest irrigation schemes. On average, 63% of all farmers indicated that they were using mulching. A study by Kodzwa et al. (2020) found that the impact of mulch on crop yield was more beneficial in the season characterised by low rainfall and extended dry spells. This demonstrates the importance of the practice of mulching as a strategy against frequent droughts induced by climate change and variability. The main reasons provided for not using mulching in the two irrigation schemes were lack of knowledge about the practice (14.4%) and that it was not important or there was no need for it (10.6%) (Table 16).

Table 16 . Reasons for not practising mulching in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		**Percentage**		**Total**	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Does not know about mulching	14	1	23.3	2.3	15	14.4
No reason provided	3	3	5.0	6.8	6	5.8
Plan to use it later	1	0	1.7	-	1	1.0
Not important – No need	5	6	8.3	13.6	11	10.6
Sell the material	2	-	3.3	-	2	1.9
Use the material as feed	1	-	1.7	-	1	1.0
Time consuming	-	1	-	2.3	1	1.0
Not applicable	32	33	53.3	75	65	62.5
Other	2	-	3.3	-	2	1.9
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

6.3.3 Water harvesting

Water harvesting refers to different practices which have been used for centuries in dry areas to collect and utilise water efficiently (Velasco-Muñoz et al., 2019). The responses of farmers to the question of why they were not using water harvesting are presented in Table 17. About 60% of the farmers mentioned that they were practising water harvesting. According to Bafdal and Dwiratna (2018), rainwater harvesting has a series of advantages, including mitigation during climate change by ensuring water availability during periods of scarcity. Moreover, it allows for the expansion of arable land, particularly in arid regions where water is the only limiting factor. New Forest had a smaller proportion (40%) of farmers practising water harvesting than Matsika (88.6%). The main reason for not using water harvesting in New Forest was that there was enough water from the dam (25%) and this made it unnecessary to practise water harvesting.

Table 17. Reason for not practising water harvesting in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		**Percentage**		**Total**	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Not applicable	24	39	40.0	88.6	63	60.6
No need as there is enough water from the dam	15	-	25.0	-	15	14.4
Afraid water tank may be stolen	4	-	6.7	-	4	3.8
No reason provided	7	1	11.7	2.3	8	7.7
No information regarding importance thereof	4	1	6.7	2.3	5	4.8
Cannot afford it	5	1	8.3	2.3	6	5.8
Other	1	2	1.7	4.5	3	2.9
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

6.3.4 Drought-tolerant seeds

Table 18 presents the responses of farmers to the question of why they were not using drought-tolerant seeds. About 76% of all farmers indicated that they were using drought-tolerant seeds. The proportions of farmers using drought-tolerant seeds were 70% in New Forest to 84% in Matsika. Walker and Alwang (2015) posit that in the last four years, there has been a significant increase in the adoption and use of drought-tolerant seeds in sub-Saharan African countries. The reason could be that adapted seeds are estimated to have increased productivity by an average of 47% and played a significant role in reducing poverty (Walker and Alwang, 2015).

Reasons given for not using drought-tolerant seeds included a lack of knowledge about it, it was costly and there was no need for using it.

Table 18. Reason for not using drought-tolerant seeds in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		**Percentage**		**Total**	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Not applicable	42	37	70.0	84.1	79	76.0
No knowledge of it	5	-	8.3	-	5	4.8
Expensive	4	3	6.7	6.8	7	6.7
No reason provided	4	2	6.7	4.6	6	5.8
No need for it	2	1	3.3	2.3	3	2.9
Other	3	1	5.0	2.3	4	3.8
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

6.3.5 Chemical fertilisers

In Table 19, the responses of farmers to the question of why they were not using chemical fertiliser are presented. There were 5 (8%) and 15 (34%) farmers who indicated that they were not using chemical fertiliser at New Forest and Matsika, respectively. In the case of Matsika, most of the farmers indicated that they could not afford to pay for chemical fertiliser (11.4%) or did not see the need to use it (11.4%). At New Forest, the reasons given for not using chemical fertiliser included a preference for organic fertiliser (3.3%) and the inability to pay for it (1.7%).

Table 19. Reason for not using chemical fertiliser in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		Percentage		Total	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Not applicable	55	29	91.7	65.9	84	80.8
Prefer organic fertiliser	2	1	3.3	2.3	3	2.9
Cannot afford – expensive	1	5	1.7	11.4	6	5.8
Plan to	1	-	1.7		1	1.0
Not aware of it	1	-	1.7		1	1.0
No need		5		11.4	5	4.8
No access	-	1		2.3	1	1.0
Other	-	3		6.8	3	2.9
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

6.3.6 Site-specific fertiliser application

Table 20 presents the responses of farmers to the question of why they were not practising site-specific application of chemical fertiliser. About 26% of the farmers were not practising site-specific application of fertiliser.

Most of the farmers at Matsika and New Forest indicated that they were already practising site-specific application of fertiliser (85% for New Forest and 59% for Matsika). The few farmers (8% and 9% for New Forest and Matsika, respectively) not practising site-specific application of fertiliser indicated that they knew nothing about it.

Table 20. Reason for not practising site-specific application of fertiliser in Matsika and New Forest irrigation schemes (n=104)

	No. of respondents		**Percentage**		**Total**	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Not applicable	51	26	85.0	59.1	77	74.0
Does not know about it	5	4	8.3	9.1	9	8.7
No reason provided	2	11	3.3	25.0	13	12.5
Other	2	3	3.3	6.8	5	4.8
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

6.3.7 Irrigation scheduling

Almost all the farmers in the two irrigation schemes indicated that they were practising irrigation scheduling. A total of 10 farmers (4 at New Forest and 6 at Matsika) indicated that they were not practising irrigation scheduling. These farmers did not find any need to practise irrigation scheduling.

6.4 Factors Inhibiting Technology Adoption – Farmers' Perspective

Farmers were asked to indicate the factors inhibiting the adoption of new irrigation technologies inherent in their production. Table 21 provides information on what farmers considered to be the main factors limiting the adoption of irrigation technologies at Matsika and New Forest irrigation schemes. Most farmers (42%) at New Forest regarded limited access to information about the technology as the main factor. At Matsika, 34% of the farmers mentioned that they would prefer to wait until they have observed other farmers achieving success with the technology. Rankoana (2022) agrees that late adoption of technologies and innovations is common among rural smallholder farmers in South Africa. The risk associated with the adoption of new technology was cited by farmers at Matsika (16%) and New Forest (3%) irrigation schemes as another factor limiting the adoption of irrigation technology. Overall, about 72% of farmers mentioned the following as the main factors inhibiting technology adoption: waiting for others to achieve success with the new technology (25%), limited access to information about new technology (31%) and lack of resources to adopt the technology (16%). In addition, Ayisi et al. (2022) found that age of a farmer (older), level of education and farm income had negative effect on farmers adopting agricultural technologies. Diederen et al. (2003) found that structural characteristics such as farm size, market position, solvency, age of the farmer explain the difference in adoption behaviour between innovators early adopters and laggards.

Table 21. Factors inhibiting adoption of new irrigation technologies in Matsika and New Forest – perspectives of farmers (n=104)

	No. of respondents		Percentage		Total	
	New Forest	*Matsika*	*New Forest*	*Matsika*	*Respondents*	*%*
Prefer seeing success by other farmers prior to own adoption	11	15	18.3	34.1	26	25.0
Limited access to information	25	7	41.7	15.9	32	30.8
Lack of resources	11	6	18.3	13.6	17	16.3
Concerns about risk of the innovation	2	7	3.3	15.9	9	8.7
Other	11	9	18.3	20.5	20	19.2
Total	**60**	**44**	**100**	**100**	**104**	**100**

Source: Field Survey (2022)

The adoption of innovations (i.e. new technologies and practices) is critical to the ongoing development of agriculture. Agricultural innovations are key drivers in the sustainable intensification of systems, potentially leading to increases in productivity, input use efficiency, profitability, resilience, and/or food and nutritional security (Jain et al., 2023). However, before these potential benefits are unlocked, farmers must decide to adopt the innovations, depending on a broad and complex range of factors. Farmers were asked to indicate the technology adopter category they belonged to. In both irrigation schemes, most farmers (New Forest = 78.3% and Matsika = 47.7%) were innovators (i.e. they try out new innovations as soon as they learn about them) (Table 22). The findings contradict the results of Nyanga (2012) who found that rural smallholder farmers are the late majority and laggards.

Table 22. Farmers' adoption of innovative irrigation technologies in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Try out new innovations as soon as you learn about them	47	78 3	21	47.7
Wait for few others to try new innovations before you do so yourself	8	13.3	5	11.4
Try new innovations after seeing sasses by many others	3	5 0	11	25.0
Try out new innovations after everyone has done so	1	1.7	5	11.4
Total responded	59	98 3	42	95.5
Missing values	1	1.7	2	4.5
Total	**60**	**100**	**44**	**100**

Source: Field Survey (2022)

6.5 Socio-economic environment

The socio-economic environment within which smallholder irrigation operates affects the adoption of irrigation water-efficient technologies. Chapter 4 has assessed the socio-economic environment within which the irrigation schemes operate. Chapter 5 focused on the technologies used by smallholder irrigation farmers in the irrigation schemes. Chapter 4 confirmed that the irrigation schemes operate in an environment characterised by poor physical infrastructure, high levels of unemployment, low levels of education and poor access to markets. These have a negative effect on the adoption of water-efficient irrigation technologies.

6.6 Summary

Chapter 6 is about factors influencing the adoption of irrigation water-efficient technologies in Matsika and New Forest. The chapter is meant to identify barriers for improved uptake of water-efficient technologies by smallholder irrigation farmers, which is the overall objective of the study. The results show that more than 60% of the farmers in New Forest irrigation scheme would like to replace the flood/furrow irrigation system. However, they are unable to do this due to lack of funding. A smaller proportion of farmers (32%) at Matsika would like to replace the irrigation system but they too are unable to do so due to lack of resources.

Regarding crop production practices/technologies, only about 26% of the farmers in the two irrigation schemes do not practise conservation tillage. These farmers prefer to use traditional cultivation methods as they find conservation tillage time-consuming and costly. Although many farmers in the two irrigation schemes use mulching, some of the farmers do not use it for reasons such as lack of information, satisfaction with the current cultivation practice and the fact that soil mulching is time-consuming. On average, about 35% of the farmers do not practise water harvesting as they do not think it is necessary. Drought-tolerant seeds are widely used in the two irrigation schemes and the few farmers (20%) that did not use these seeds mentioned high cost and lack of information as the reasons. Regarding irrigation scheduling, only about seven percent of the farmers did not practise it as they did not think it was important. Finally, the two irrigation schemes operate in an environment characterised by poor infrastructure, high levels of unemployment, low levels of education and poor access to markets. All these have a negative effect on the adoption of irrigation efficient technologies.

CHAPTER 7: THE ROLE OF CHANGE AGENTS IN THE ADOPTION OF IRRIGATION WATER EFFICIENT TECHNOLOGIES

7.1 Introduction

This chapter focuses on the role of change agents/extension advisors in the adoption of irrigation water-efficient technologies in the irrigation in Matsika and New Forest irrigation schemes. Extension advisors may influence the adoption of water-efficient technologies in various ways including through training of farmers and provision of advisory services. One of the reasons extension advisors are employed in the public service is because of their expertise and assumed enthusiasm for innovative change. This chapter considers whether farmers in Matsika and New Forest have access to extension services. The issue of who provides the services and the preferred methods of receiving the services or transferring technology are also considered. The chapter also addresses the issue of training provided to farmers and what the training focuses on. This is meant to inter alia determine whether farmers receive training on water-efficient technologies.

Subsequent sections of the chapter are organised as follows: Subsequent sections of the chapter are organised as follows: Section 7.2 discusses the accessibility of extension services for farmers and the organisations supplying the services. This is followed by Section 7.3 which presents the results on the preferred methods of technology transfer. Section 7.4 presents information on the area of focus for extension and advisory services. The preferred methods of digital communication are covered in Section 7.5. Section 7.6 provides information on the main suppliers of training for farmers. The type of training received by farmers and whether training on water use was provided are discussed in Sections 7.7 and 7.8, respectively. Section 7.9 provides a summary of the chapter.

7.2 Accessibility and Suppliers of Extension Services

Table 23 shows that the largest proportion of the farmers had full access to extension services in New Forest (48.3%) whilst the majority (59.1%) of farmers at Matsika had partial (limited) access to extension services. The primary sources for extension and advisory services were government officials at the local municipality level. This was expected because the officials are field agents working directly with farmers. Farmers were asked to select top institutions that provided extension and advisory services to the irrigation schemes. At New Forest, the largest proportion (36.7%) of farmers indicated that a combination of the national and provincial departments of agriculture was the top provider of extension services.

The proportion of farmers at Matsika that indicated that they received extension services from a combination of NGOs and provincial departments of agriculture on the one hand and national and provincial departments of agriculture on the other was 29.5%. The results indicate that most farmers in the irrigation scheme had access to extension and advisory services and the main sources were the three levels of the public sector. The findings concur with those of previous studies that the public sector is the dominant source of extension and advisory service among smallholders in rural areas of South Africa (Liebenberg, 2015; Terblanche and Koch, 2013; DAFF, 2016; Khwidzili, 2019; Loki et al., 2021).

Table 23. Accessibility and sources of extension services in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Accessibility				
Fully accessible	29	48.3	14	31.8
Partially accessible	20	33.3	26	59.1
Not at all accessible	11	18.3	4	9.1
Primary sources of extension services				
Local Municipal level	31	51.7	32	72.7
District Municipal level	9	15.0	6	13.6
Provincial level	18	30.0	5	11.4
National level	2	3.3	1	2.3
Other institutions that provide extension services				
National department	12	20.0	3	6.8
NGOs	2	3.3	1	2.3
Commodity group(s)	1	1.7	9	25
Provincial government	12	20.0	1	2.3
National department and Commodity group	5	8.3	4	9.1
National department and provincial	22	36.7	13	29.5
NGO and provincial	3	5.0	13	29.5
Provincial and commodity	1	1.7	4.4	10.0

Source: Field Survey (2022)

7.3 Preferred Method of Technology Transfer

Farmers were asked to indicate their preferred method of technology transfer to advance learning and adoption of agricultural innovations and technologies. As shown in Table 24, farmers in both irrigation schemes (46.7% in New Forest and 84.1% in Matsika) prefer on-field demonstrations. Visits to individual farmers were preferred by 35% of farmers at New Forest.

Table 24. Preferred method of technology transfer to advance learning in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
On field demonstration	28	46.7	37	84.1
Media (Radio, TV, social)	-	-	1	2.3
Farmers day	10	16.7	-	-
Visits to individual farmers	21	35.0	4	9.1
Study groups	-	-	2	4.5
Total responded	59	98.3	44	-
Missing values	1	2.3	-	-
Total	60	100	44	100.0

Source: Field Survey (2022)

7.4 Focus Area of Extension and Advisory Services

Extension officers are often directed by policy to focus on specific areas of farm productivity based on the needs of the farmers, inputs and available natural resources in a particular community. Table 25 shows that 61.7% of farmers at New Forest and 50% in Matsika, extension and advisory services focused on general farm production. This was followed by market advice at New Forest (18.3%) and a combination of production and marketing advisory services at Matsika (11.4%). The findings concur with the results of Ngemntu (2010) and Loki et al. (2021) that extension officers focus mainly on marketing and primary production-related services.

Table 25. Focus area of the extension and advisory services by the change agents in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Production advice	37	61.7	22	50.0
Market advice	11	18.3	2	4.5
Climate adaptation	1	1.7	-	-
Innovation technologies	3	5.0	1	2.3
Production and marketing	-	-	5	11.4
All of the above	-	-	11	25.0
Others	3	5.0	-	-
Total responded	55	91.7	41	93.2
Missing values	5	8.3	3	6.8
Total	**60**	**100**	**44**	**100**

Source: Field Survey (2022)

7.5 Preferred Digital Communication Tools

Providing timely information that is not influenced by logistical, infrastructural, and environmental factors aimed at improving the agricultural practices of smallholder farmers remains a challenge in many developing countries. Traditional dissemination methods like in-person meetings or radio programming can be costly to scale or offer too generic information. As shown in Table 26, digital communication tools frequently used by agents of change for extension and advisory services in New Forest (78.3%) and Matsika (81.8%) were cellular/mobile phones. When asked about their preferred digital tool for extension services, most farmers in both schemes (78.3% and 86.4% at New Forest and Matsika, respectively) reiterated that cellular phones were their preferred tool to communicate extension and advisory services.

Table 26. Current and preferred digital tools communication used for extension services in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Current digital communication tools used for Extension				
Cellular phone	47	78.3	36	81.8
Laptop computer	-	-	1	2.3
Smart pen	3	5.0	1	2.3
Other	8	13.3	5	11.4
Preferred digital tool for extension Services				
Cellular phone	47	78.3	38	86.4
Laptop computer	2	3.3	2	4.7
Desktop computer	-	-	1	2.3
Smart pen	2	3,3	-	-
Farm visits	9	15.0	-	-
Other	-	-	2	4.5

Source: Field Survey (2022)

As shown in Table 27, the government provides nearly all the training received by the farmers in both irrigation schemes. The findings concur with Mapiye et al. (2021) who posited that public extension is the main source of training and technology transfer for small-scale farmers in developing countries.

Table 27. Stakeholders investing in the training of farmers in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Government	54	90.0	43	97.7
Private sector/Commodity group	1	1.7	-	-
Other commercial farmers	2	3.3	1	2.3
Total responded	57	95.0	44	100
Missing	3	5		
Total	**60**	**100**	**44**	**100**

Source: Field Survey (2022)

7.6 Type of Training Received

The results indicate that many farmers (81.8%) at Matsika received training on varied agricultural practices (see Table 28). However, this was not the case at New Forest where 56.7% of the farmers indicated that they did not receive training. As regards the type of training received, 40% of the farmers at New Forest were trained on farm production. At Matsika, 52.3% of the farmers indicated they received training on production, project management and the use of irrigation technologies.

Table 28. Recent training and type of training received in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Recent training Received				
Yes	25	41.7	36	81.8
No	34	56.7	8	18.2
Type of training received in the past				
Production	24	40.0	4	9.1
Project management	1	1.7	1	2.3
irrigation technology use	1	1.7	9	20.5
All of the above	-	-	30	52.3

Source: Field Survey (2022)

7.7 Training on Water Use

Farmers were asked whether they received training or advice from the extension officers regarding water use. At New Forest, most farmers (65%) indicated that they had not received any advice or training regarding water use, whilst about 57% of farmers at Matsika received some advice on water use (see Table 29).

Table 29. Advice or training received from the extension officers on water use in Matsika and New Forest irrigation schemes (n=104)

	New Forest		Matsika	
	Respondents	**Percentage**	**Respondents**	**Percentage**
Yes	21	35	25	56.8
No	39	65	19	43.2
Total	60	100	44	100

Source: Field Survey (2022)

7.8 Summary

This chapter is about the role of change agents in the adoption of water-efficient technologies in Matsika and New Forest irrigation schemes. An important role of agricultural extension services is to disseminate technologies to farmers. Most farmers in the two irrigation schemes had access to extension services at varying levels. The primary sources for extension and advisory services were government officials at the local municipality level. The extension and advisory services focused on general farm production and marketing advice. Regarding the type of training, 40% of the farmers at New Forest indicated that they were trained on farm production. At Matsika, 52% of the farmers indicated they had received training in production, project management and the use of irrigation technologies. Most farmers (65%) at New Forest indicated that they had not received any advice or training regarding water use, whilst about 57% of farmers at Matsika received some advice on water use. Regarding the preferred method of disseminating information and technologies, most farmers preferred on-field demonstrations, followed by visits to individual farmers. Cellular phones were the most preferred digital tool to communicate extension and advisory services.

CHAPTER 8: SUMMARY, CONCLUSION AND RECOMMENDATIONS

8.1 Summary

8.1.1 Background

South Africa is a water-scarce country and, therefore, water needs to be used efficiently. In an era where environmental concerns have taken centre stage, the importance of water conservation and efficiency cannot be overstated. The biggest user of water in the country is the agricultural sector and ovrer 60% of water is used for irrigation. Therefore, it is important to improve the efficiency of water use in this sector. Within the agricultural sector, it is particularly essential to improve the efficiency of water use within smallholder irrigation. This will require the adoption of efficient irrigation technologies. However, smallholder farmers face numerous challenges in adopting these technologies.

8.1.2 Objectives

This study was undertaken to assess the barriers to improved uptake of efficient irrigation technologies in two provinces in South Africa, namely, Limpopo and Mpumalanga. The main aim of the study was to identify factors influencing the adoption of water-efficient irrigation technologies in smallholder irrigation in the two provinces. The specific objectives of the study were to (a) assess and understand the socio-economic environment within which selected small-scale irrigation communities operate; (b) identify irrigation technologies that are used in two selected small-scale irrigation schemes; (c) identify the factors that influence the adoption of irrigation water-efficient technologies; (d) assess the role of “agents of change” in the adoption of irrigation water-efficient technologies; and (e) identify possible ways of overcoming barriers to the adoption of irrigation water-efficient technologies.

8.1.3 Methods and procedures

Two irrigation schemes (Matsika and New Forest) were selected in Limpopo and Mpumalanga provinces based on their perceived performance and other criteria. Matsika was classified as a good-performing scheme while New Forest was considered a poor-performing scheme. New Forest uses flood irrigation while Matsika uses micro irrigation. Data were collected from 104 farmers using both questionnaire surveys and focused group discussions.

8.1.4 Literature review

A comprehensive review of the literature was undertaken on irrigation, especially smallholder irrigation, and the concept and process of technology adoption and factors affecting technology adoption. The review of the literature reveals that the process of technology adoption is complex and affected by numerous factors. These factors have to do with the characteristics of the farmers, characteristics of the technology, the role of change agents, institutions, and the socio-economic environment within which smallholder farmers operate. Irrigation technologies that are water-efficient in previous studies are described. These include irrigation systems such as sprinkler, drip and micro systems. They also include crop production technologies or practices such as soil mulching, conservation tillage, irrigation scheduling, and soil management.

8.1.5 Results

The socioeconomic environment within which smallholder farmers operate was assessed as it affects what happens in the irrigation scheme, including decisions on the adoption of technology. The assessment was done at different levels (irrigation scheme, village, local and district municipality) for the two irrigation schemes. Poor infrastructure and provision of quality education are serious problems in the two district municipalities of Vhembe and Ehlanzeni where the irrigation schemes are located. Illiteracy is, therefore, a barrier to agricultural development because it can lead to a low adoption rate of new and improved technologies. Poor infrastructure makes it difficult for farmers to transport their produce to the market and inputs to their farms.

The villages in which the two irrigation schemes are located exhibit some level of underdevelopment, characterised by high levels of poverty and unemployment. Notwithstanding the various developmental projects that have been implemented in these villages, there is room for improvement, especially in terms of permanent and sustainable employment creation. Therefore, based on the socioeconomic standing of these two villages, including the available resources, skills and infrastructure, sectors such as agriculture can be further developed to improve the livelihoods of the communities. Ensuring that irrigation schemes perform optimally will go a long way in advancing the contribution of agriculture to poverty reduction and employment creation.

The results of the study show that over 60% of the farmers at New Forest irrigation scheme would like to replace the flood/furrow irrigation system. However, they are unable to do this due to lack of funding. A smaller proportion of farmers (32%) at Matsika would like to replace the irrigation system but they are unable to do so due to a lack of resources as well.

As regards crop production practices/technologies, only about 26% of the farmers in the two irrigation schemes do not practise conservation tillage. These farmers prefer to use traditional cultivation methods as they find conservation tillage time-consuming and costly among other reasons. Although the majority of farmers in the three irrigation schemes use mulching, some of the farmers do not use it for reasons such as lack of information, satisfaction with the current cultivation practice and the fact that soil mulching is time-consuming. On average, about 35% of the farmers did not practise water harvesting as they did not think it was necessary. Drought-tolerant seeds were widely used in the two irrigation schemes and the few farmers (20%) that did not use these seeds mentioned the cost and lack of information as the reasons. Regarding irrigation scheduling, only about seven percent of the farmers did not practise it as they did not think it was important.

The results show that the majority of farmers had access to extension services in both irrigation schemes at varying levels. The primary sources for extension and advisory services were government officials at the local municipality level. An important role of agricultural extension services is to disseminate technologies to the farmers to improve farm production. The findings show that, although farmers did receive training on the use of irrigation technology, the role of extension officers was limited. There is little indication from the farmers that they were taught or trained on specific irrigation technologies that help reduce water wastage. Extension advice and training provided to the farmers in the two irrigation schemes focused on production aspects of farming with little attention given to training in irrigation water efficient technologies. Furthermore, farmers have made little progress in terms of adopting irrigation water-efficient technologies despite having access to extension services.

8.2 Conclusions

The two irrigation schemes investigated in this study operate in an environment characterised by poor infrastructure, high levels of unemployment, low levels of education and poor access to markets. All these have a negative effect on the adoption of irrigation efficient technologies.

It can be concluded from the results of the study that funding will be the determining factor in the adoption of efficient irrigation technologies such as sprinkler, drip and micro irrigation systems. Farmers expect the funding to come from the government as they are unable to raise it on their own.

In the case of crop production technologies, significant progress in the adoption of efficient technologies can be achieved largely by investing in farmers' knowledge about the technologies. Making farmers aware of their existence and potential benefits, accompanied by training and advice on how to use the technologies, can play an important role in removing barriers to the adoption of water-efficient crop production technologies. Addressing factors limiting technology adoption (e.g. physical infrastructure, and markets) in the socio-economic environment within which the irrigation schemes operate would assist in promoting the adoption of water-efficient technologies.

The work of agricultural extension is critical for the development of the smallholder agricultural sector. Without agricultural extension, many smallholder farmers will not benefit from modern agricultural techniques and new agricultural information. Agricultural extension is an important role player in the transfer of agricultural technologies to farmers and in convincing them to adopt modern agricultural techniques. The conclusion from the results of the study is that extension officials have insufficiently carried out their role of transferring and training farmers on irrigation water-efficient technologies. The results show that the focus of extension services has been on general farming activities and information transfer. There is limited attention to the training of farmers in improved technologies, including irrigation water-efficient technologies. Therefore, training should focus more on improved technology adoption and use, particularly water-efficient technologies.

8.3 Recommendations

This section presents suggestions for addressing barriers to the adoption of water-efficient technologies in the two irrigation schemes, namely, New Forest and Matsika.

8.3.1 Information about the technologies

Before adopting a technology, smallholder farmers must know about the technology and the benefits of adopting it. In addition to acquiring knowledge about the technology, farmers need to know how to use the technology to improve efficiency in the use of irrigation water. Given that some smallholder irrigation farmers included in the study mentioned that they lacked information about water-efficient technologies they did not adopt, it will be essential to implement measures that will provide information about the technologies and the benefits that can be derived from adopting the technologies.

The water-efficient technologies that farmers indicated they lacked information about included site-specific application of fertiliser, drought-tolerant seeds, mulching, no-tillage cultivation, water harvesting, and irrigation scheduling. Therefore, any measures to provide information about water-efficient technologies should at least cover these technologies. Making farmers aware of their existence and potential benefits, accompanied by training and advice on how to use the technologies, can play an important role in removing the barriers to the adoption of water-efficient crop production technologies and irrigation practices.

The methods that have proved effective in providing information to farmers about new technologies include farmer training (by extension agents), social learning (farmer-to-farmer exchange of information) and establishment of demonstration plots. Farmer training/learning can take various forms, including workshops, study tours, and extension visits. The establishment of demonstration plots in the irrigation schemes to demonstrate the benefits that can accrue from adopting water-efficient technologies can be one of the most effective ways of providing information about new technologies. Such benefits may be in the form of increased yields, higher profits and reduced water consumption. Efforts should be made to promote the sharing of information about water-efficient technologies among the farmers. Training by extension officers that focused on production aspects should place more emphasis on water-efficient technologies. The training should include creating awareness about the importance of using irrigation water efficiently and the various technologies that can be used to achieve this.

8.3.2 Resources

The adoption of technology can be quite costly and smallholder farmers often do not have the necessary resources to adopt the technology, even when they are convinced of the benefits associated with the use of the technology. This explains why external financial assistance should be provided to the farmers to facilitate the adoption of water-efficient technologies. In the case of inputs such as chemical fertilisers and drought-tolerant seeds, the assistance can take the form of government subsidies and/or low-interest credit. However, in cases where smallholder farmers wish to switch from the existing irrigation system (e.g. flood/gravity irrigation) to a more water-efficient system (e.g. sprinkler, micro or drip irrigation), government grants or donations from the private sector or NGOs may be the most effective form of financial assistance. Although smallholder farmers are often poorly resourced, this does not preclude them from taking their own initiatives to address the problem of lack of resources to adopt water-efficient technologies. For example, forming saving groups and/or cooperatives is an effective way to accumulate wealth among the poor.

8.3.3 Physical infrastructure

Addressing factors limiting technology adoption (e.g. physical infrastructure and markets) in the socio-economic environment within which the irrigation schemes operate would assist in promoting the adoption of water-efficient technologies. The government should play a crucial role in addressing issues of physical infrastructure such as roads and market facilities.

The irrigation infrastructure at New Forest is damaged in many places, resulting in major water losses. Unless these facilities are repaired, water losses will continue and any measures to improve water efficiency by adopting efficient technologies will be futile. The government will have to step in to repair the irrigation infrastructure as the repair cost is too high for the farmers. Farmers themselves will need to implement measures to safeguard the infrastructure once it has been repaired.

8.3.4 Access to markets

Access to markets for the products of smallholder irrigation farmers is an important factor affecting the adoption of water-efficient technologies. Farmers in the two irrigation schemes operate in an environment where access to markets is poor. Therefore, it is important to take measures that will improve access to input and output markets. Ensuring that farmers' cooperatives function well can be an effective way of improving access to markets.

At Matsika, the quality of bananas produced is low and this limits their marketability. In this case, it will be important to ensure the quality of bananas is improved. The farmers were optimistic about this being achieved as a lack of irrigation water, which was given as the main cause of poor-quality bananas and this problem seems to have been resolved. However, other factors may explain the poor quality of bananas. This may include poor irrigation and production practices, and inappropriate crop varieties, to mention a few. Further investigations should be carried out to determine the real causes of the poor quality of bananas.

8.3.5 Appreciation for water saving

Farmers should be incentivised to use irrigation water efficiently. It has been shown elsewhere that requiring farmers to pay for irrigation water increases the value of the water. This incentivises farmers to use water efficiently. This is something that is to be explored at Matsika and New Forest to determine if such incentives are appropriate and can lead to improved water efficiency.

8.3.6 Monitoring the use of water and adoption of water-efficient technologies

Measures should be taken to monitor the use of irrigation water and the adoption of water-efficient technologies. This can be done by government officials in collaboration with the farmers.

8.3.7 Irrigation scheduling

Data on weather patterns, water availability, and soil moisture levels, to mention a few, should be provided to smallholder farmers so that they can practise irrigation scheduling. With developments in communication technologies, it should be easy to share such information with farmers. However, obtaining tools required for effective irrigation scheduling can be costly and farmers may not be in a position to pay for them. It should also be established whether real irrigation scheduling can be implemented given the way irrigation plots in the irrigation schemes are organised.

8.3.8 Land grabbing

Farmers at New Forest have been unable to address the problem of their cropland being taken away and used for residential purposes. This problem can best be addressed by law enforcement agencies or other authorities (e.g. local authorities and traditional leaders).

8.3.9 *Conflicts*

Measures should be taken to improve working relations between the farmers and government officials, especially at Matsika. Ideally, this should involve a third party as farmers and government officials are unlikely to resolve the existing conflict themselves. At New Forest, there were conflicts among the farmers that resulted in the collapse of their cooperative. These conflicts will also need to be addressed with external assistance. In addition to seeking third-party assistance, *it is recommended that farmers be provided with training to equip them with skills that can assist in conflict resolution and efficient management of irrigation schemes.* These skills may include communication, conflict resolutions, teamwork, and management which can be imparted through adult education.

8.3.10 Non-operational farmers' organisations

The formation of farmer cooperatives (or their strengthening where they already exist) should be promoted to manage irrigation schemes, invest in irrigation infrastructure, and provide inputs and marketing services for the farmers. Farmers at New Forest should be assisted to revive their cooperative. This should entail finding out the nature of conflicts among the farmers that resulted in the collapse of the cooperative that was functioning well and taking steps to address the conflicts. An external mediator would be ideal for resolving the conflicts. Once the conflicts have been resolved, the farmers can be assisted to revive the cooperative and to put in place measures that will prevent it from collapsing again. Such measures are likely to include teaching the farmers about the cooperative way of doing things.

8.3.11 Management of the irrigation schemes

The management of Matsika irrigation scheme should be restructured to ensure that it is representative of the farmers and acts in their interest. It is not in the best interest of the farmers for the management to be dominated by a single individual.

8.4 Recommendations for Further Research

There are numerous gaps in our knowledge of efficient-irrigation technologies that need to be addressed in future research. The following are recommended for future research:

1. Our research did not consider the issue of dis-adoption, which has become important in research on technology adoption. By not considering dis-adoption, we will not know whether those who indicated they were not using/practising efficient-irrigation technology previously used/practised these technologies. Also, those using/practising efficient-irrigation technologies could have dis-adopted some of the technologies. The reasons for dis-adoption would have been important to establish.
2. Our report is largely qualitative due to data limitations. A quantitative study would have generated more revealing findings.
3. A more detailed analysis of the factors affecting the adoption of each specific irrigation-efficient technology would have yielded better results. Our study considered the various technologies but did not go deeper into each one of them to gain more understanding of what may affect their adoption.
4. Future research should consider the extent to which the training provided by extension officers and others has been adopted and applied.
5. Future research should consider the impact of the adopted irrigation-efficient technologies on water use efficiency and agricultural production.

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APPENDIX A: QUESTIONNAIRE

ASSESSMENT OF BARRIERS FOR IMPROVED UPTAKE OF IRRIGATION WATER EFFICIENT TECHNOLOGIES BY SMALL-SCALE FARMERS IN TWO SELECTED PROVINCES

QUESTIONNAIRE FOR BASELINE SURVEY IN LIMPOPO AND MPUMALANGA PROVINCES (SOUTH AFRICA)

DATE ___/______/2022 TIME STARTED …………….TIME ENDED…………..

Name of Enumerator ____

INFORMATION SHEET

Good (morning/afternoon/evening), my name is ____. I am part of a research team from the Universities of Pretoria and Limpopo. We are here to ask questions in relation to the study requested by the Water Research Commission (WRC). The study is in connection with assessment of barriers for improved uptake of irrigation water efficient technologies by small scale farmers in two selected provinces, namely Limpopo and Mpumalanga.

The WRC and the universities seek to understand the barriers or constraint related to improved uptake of irrigation water efficient technologies by small scale farmers. As you may be aware that water is a scarce resources, which heightens the importance of irrigation for production purposes.

Working with the provincial-based extension officers supporting the study, the research team has identified small scale irrigation farmers and beneficiaries from the two irrigation schemes in the two provinces. You were identified as a farmer and/or beneficiary who can assist us in responding to the set questions. The questionnaire will take about one hour to complete, and we would need your commitment and attention during this time to talk about your involvement in the irrigation scheme and other matters concerning what takes place within the scheme. We may contact you at a later date for follow up purposes.

Please understand that you are not being forced to take part in this study. Your participation in this interview is voluntary. You have the right to refuse to participate in this study, to refuse to answer specific questions, or to discontinue the interview at any time. If you do this, you will NOT be prejudiced in ANY way. But your views are important, and will help key stakeholders to determine how best irrigation schemes in South Africa can be improved to ensure maximized production and other related benefits. In answering the questions, there will be no right and wrong answers. All Standard Operating Procedures (SOP) for conducting field-based research of this nature will be followed.

There will be no direct benefits to you from the study itself. The study will hold no risks for you or to any other member of your scheme. But intend to bring change and assist in decision making by supportive stakeholders. All information that youprovide will be kept confidential and you will not be identified by name or address in any of the reports that we plan to write. It will be impossible to link back to you the information you share with us. For most of the questions, we will list choices and you can pick the most relevant one.

If you have questions or concerns about the research in general or about your role in the study, please feel free to contact Professor Charles Machethe of the University of Pretoria by email at Charles.machethe@up.ac.za or by phone 012 420 3280. You may also contact Professor Mmapatla Precious Senyolo at the University of Limpopo via email at mmapatla.senyolo@ul.ac.za or byphone 015 268 4628 or Mrs. Mutondi Mmushi via email at ptondy@gmail.com, Tel no 012 319 8300

By participating in this study, you confirm that you are over 18 years of age.

Do you consent to participate in this survey? Check one option √

0=no	**1=yes**	**If no, end the survey.**

DECLARATION BY ENUMERATOR

DECLARATION BY FIELDWORKER

I hereby declare that I explained to the respondent that she or he is participating freely in this study. I also explained to the respondent that she or he may stop this interview at any point and that such a decision would not in any way affect them negatively.

I explained to the respondent that this is a baseline study whose purpose is not necessarily to benefit her or him personally.

I explained to the respondent that the answers she or he will provide during the interview would remain confidential.

Signature of enumerator: ………………………………………………… Date: …………………………

TO BE COMPLETED BY ENUMERATOR

1. Enumerator details: First name and surname						
2. Particulars of visit(s) to household	**Yea r**	**Mont h**	**Dat e**	**Time started**	**Time finished**	**Response (ENTER RESPONSE CODE**

RESPONSE CODE	Completed questionnaire	01	Interview refused by selected respondent	06
	Selected respondent not available	02		
	Respondent cannot communicate with interviewer because of language	03		
	Respondent is physically/mentally not fit to be interviewed	04		
	Partially completed questionnaire (specify reason)	05		

TO BE COMPLETED BY SUPERVISOR AFTER INTERVIEW

1. Name of Supervisor and date checked

_______ _______ __ ______ __ __ ___

2. Signature of Supervisor

_______ ________ __ _________ ___

1: DETAILS OF THE IRRIGATION SCHEME, RESPONDENT, AND HOUSEHOLD

1.1 Name of irrigation scheme:

1.2 Name of village:

1.3 Name of ward:_

1.4 Name of district municipality:

1.5 Name of province:

1.6 Respondent's name (s):_

1.7 Respondent's cellphone number:
_

1.8 Respondent's relationship to the household head (HH) Code [_________]

1 = Household head	2 = Spouse	3 = Child	4 = Other relation (specify)	5 = Other member (non-relative)

1.9. Marital status of household head Code [_]

1 = Married	2 = Single	3 = Divorced/ separated	4 = Living together	5 = Widow / widower	6 = Other (specify)

1.10 Number of years the household head has lived in this village [_
]

1.11 Number of years the farmer has been farming: [
]

1.12 Number of years the farmer has been farming on the irrigation scheme: [_
_]

1.13 Number of people actively involved on the plot: [
]

Full time:	Part time:	Seasonal:

1.14 Give details of household members (including HH head) living permanently at home or mostly away from home but contributing or demanding significantly from the household resources (e.g. son in Gauteng sending cash, boarding pupil)

ID	Relationship to HH head (code)	Sex (1=male; 2=female)	Age (years)	Number of years of schooling (years)	Primary activity (code)	Home occupancy (1=permanent; 2=mostly away)
1	HH head = 1					
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						

RELATIONSHIP TO HEAD	YEARS OF SCHOOLING	PRIMARY ACTIVITY
1 = Household head 2 = Spouse 3 = Child 4 = Other relation (specify) 5 = Other member (non-relative)	0=illiterate 1= Sub A Grade 1 2= Sub B Grade 2 3= Standard 1 Grade 3 4= Standard 2 Grade 4 5= Standard 3 Grade 5 6= Standard 4 Grade 6 7= Standard 5 Grade 7 8= more than 7 years	1 = Infant (<6years) 2 = Student 3 = Farmer (on this farm) 4 = House/farm help (on somebody else's farm) 5 = Government/ parastatal employee 6 = Private sector employee 7=Self-employed (non-farm) 8= Migrant 9= Not working, old or disabled 10 =Other (specify)

2. HOUSEHOLD INCOME SOURCES, LIVELIHOOD ACTIVITIES AND EXPENDITURE

2.1 For each household member listed in 1.14, who is mostly away from home, please provide the following information:

ID (obtain from 1.14)	Number of years away	Current place of residence (town, country)	Sent money home last 1yr? (1=yes; 2=no)	Number of times last 1yr	Average amount sent

2.2 Please provide an estimate of your total **monthly** household income, from all **working members at home**, business income, and pensions (**excluding remittances** accounted for in 1.15 above) [__] R/month.

3. If the respondent finds it difficult to answer this question, ask about range: [_______________]

4.

1= Below R1,000/ month
2= Between R1,000 and R2,000/month
3= Between R2,000 and R5,000/month
4= Above R5,000/month

5. Rank the different sources of income

5.1 for the household

For ranking: 1= main source of income, 2= 2nd, 3 = 3 rd, 4 = smallest source of income

Sources of income	Rank
Income from all livestock activities	
Income from all crop activities	
Income from wages/salaries/non-farm, pension and business activities	
Income from remittances from absent family members and other external income	
Income from other sources, specify: _______________________	

5.2 Please provide information on what people in this household do for a living (in addition to what has been previously listed) (enumerator checks livelihood activities mentioned by household)

Activity	Tick livelihood activities in the last 1 year! Oct 2021-Nov 2022	Amongst those livelihood activities, rank the most important sources of cash income (1, 2, 3, 4, etc.)
Rearing livestock (everyone!)		
Livestock products (meat, milk, eggs)		
Trading livestock (buying and selling)		
Renting out livestock (draft power, insemination)		
Food crop production		
Feed and fodder production		
Gardening/vegetable production		
Farm land rent or sharecropping		
Natural products (e.g. charcoal, firewood, water, thatching grass)		
Craft, carpentry, weaving, basket making, pottery, etc.		
Bricks, construction		
Food and drinks		
Transport		
Barber/hairdresser		
Musician		
Traditional healer		
Petty trade, buying and selling (except livestock)		
Cross border trade		
Formal employment		
Working on other farms		
Pensions, cash aid		
Part time job		
Hunting and fishing		
Other (specify)		

5.3 Rank the different sources of income from **farming** activities. For ranking: 1= main source of income, 2= nd, 3= 3 rd , etc

Sources of income from the farm activities	**RANK**
Income from other livestock activities	
Income from sale of cash crop products	
Income from sale of food crop products	
Income from sale of horticultural crops	
Income from other farm activities (including bee keeping, manure)___________________	

5.4 Please provide an estimate of your household's **monthly** expenditure.

HOUSEHOLD EXPENDITURES **HOUSEHOLD EXPENDITURE CODES**		**Monthly expenditures How much does the household spend on (…)?** **ENTER *ESTIMATED AMOUNT* FOR ALL ITEMS PURCHASED MONTHLY**
Food	01	
School fees, uniforms, books	02	
Clothes	03	
Furniture (instalments)	04	
Transport (bus fares, taxis fees)	05	
Vehicles including instalments	06	
Energy/electricity	07	
Burial and savings society or stokvel	08	
Personal items (toiletries, washing powder)	09	
Telephone (cellular phone, talk time)	10	
Water (transport, purchase, pumping)	11	
House maintenance	12	
Health medicine treatment (traditional)	13	
Other (Specify)	14	

	15	
	16	
	17	

6. Land ownership and use, crop production and marketing, and asset ownership

6.1 Please provide information on access to land and land use.

Plot ID	Size of each plot (ha)	Land ownership (code)	Current land use (for land used by household) (code)
1			
2			
3			
4			
5			
6			
7			
8			
9			

LAND OWNERSHIP	LAND USE
1 = Family owned 2 = Rent in (no payment) 3 = Rent out (payment) 4 = Rent in (payment) 5 = Title 6 = Other (specify)	0 = Idle; fallow 1 = Crop cultivation 2 = Livestock grazing/fodder/fodder trees 3= Fruit Trees/ gardening 4 = Other (specify)

6.2 Please provide information on crops grown, amount harvested and sold in the last year (Oct 2021-Nov 22)

Crop grown (codes)	Area size	Unit for area	Unit for harvest, sale and price	Amount harvested	Amount sold	Total price (R/ unit)	Production cost (R/unit)

CROPS GROWN

1=Maize 2=Sorghum 3=Millet 4=Beans 5=Groundnuts	6=Cashew nuts 7=Cowpeas 8=Tomato 9=Pumpkins/melons 10=Watermelons	11=Onion 12=Cabbage/rape 13=Irish potato 14=Sweet potato 15=Cassava	16=Yam 17=Arrow root 18=Grass 19=Dual-purpose cereals	20=Legume shrubs 21=Legume trees 22= Other (specify)

UNIT FOR LAND SIZE	
1= ha 2=tree 3=other (specify) UNIT FOR HARVESTS, SALES AND PRICE 1= kg 2=bag (specify conversion factor into kg) 3= other (specify)	

6.3 If you sold some products, who was the buyer?

6.4 If sold in the market, what is the distance between the farm and the market?
km

6.5 Who is your input supplier? ____

6.6 What is the distance between the farm and the input supplier?______________km

3.3 Please provide information on asset ownership by your household

Assets	Number ow ned now	Assets	Number ow ned now	Assets	Number ow ned now
Radio		Shovel			
Television		Axe			
Phone		Bush knife (panga)			
Vehicle		Plough			
Motorcycle		Wheel barrow			
Bicycle		Sewing machine			
Tractor		Refrigerator			
Hoe					
Scotch cart					

3.4 Please provide information on the housing material used for the homestead and the number of rooms/units.

Mostly used roofing material (code)	Mostly used wall material (code)	Total number of units/rooms (count)
ROOFING MATERIAL	WALL MATERIAL	
1=Thatch grass 2=Iron / asbestos sheet 3=Tiles 4=Other(specify)	1=Pole and mud 2=Burned brick and mud 3=Unburned brick and mud 4=Brick plastered with cement	5=Stone 6=Other(specify)

Farming practices

No	Items	Response		
4.1	Do you practise no-tillage?	1= Yes	2= No	If no, why?
4.2	Do you practise soil mulching?	1= Yes	2= No	If no, why?
4.3	Do you practise water harvesting?	1= Yes	2= No	If no, why?
4.4	Do you use drought tolerant seeds?	1= Yes	2= No	If no, why?
4.5	What type of seed is used for each crop?	1=Improved	2= Traditional	
4.6	Do you use chemical fertilizers to improve productivity	1=Improved	2= Traditional	If no, provide reason: If yes, how do you

4.7	Do you practise site-specific application of nutrients (fertilizers)?	1= Yes	2= No	If no, why?
4.8	Do you keep records for the farm	1= Yes	2= No	If no, why?

7. SOIL TYPES

NO	ITEM	RESPONSES						
5.1	Which soil types are predominant on the farm?	1=Sandy	2=Clay	3=Silty	4=Loamy	5=Peaty	6=Chalky	7= other (specify)
5.2	What is the quality of soil on the farm?	1= Very good		2= Good		3= Poor		
5.3	If there are deficiencies in soil, what is it deficient in?							
5.4	Do you experience any soil erosion?	1=None		2=Mild			3= Severe	
5.5	Do you experience any problem of waterlogging or drainage?	1 = Yes		2 = No			3= If yes, how do you resolve it?	

6. IRRIGATION INFRASTRUCTURE AND ITS MANAGEMENT

NO	ITEM	RESPONSES

6.1	What types of irrigation system(s) are you aware off?	1= Drip irrigation	2=Flood/furrow irrigation	3=Sprinkler irrigation	4= Micro irrigation	5= Other (specify)
6.2	Which of these irrigation systems do you consider efficient in water use?	1= Drip irrigation	2=Flood/furrow irrigation	3=Sprinkler irrigation	4= Micro irrigation	5= Other (specify)
6.3	Are the systems selected in 6.2 your preferred ones?	1=Yes				2=No
6.4	Who installed the irrigation system on the irrigation scheme?	1= National government	2= NGOs	3= Commodity group/s	4= Provincial government	5= International actors
6.5	If the existing irrigation system is not among the efficient ones, would you prefer to replace it?	1=Yes	2=No	3= If Yes, what would need to happen for it to be replaced?		
6.6	If it is not possible or desirable to replace the existing irrigation scheme, what can be done to improve the efficiency of water use?			Specify:		
6.7	Do you practise irrigation scheduling?	1=Yes:	2=No	3= If yes, describe the type of scheduling		4= If no, what are the reasons?
6.8	How frequent is irrigation system maintenance carried out?	0=Never	1=As per need	2=Every 6 months	3= Every year	4= Other (specify)

6.9	Which components of the irrigation system require frequent maintenance?	(Name 2)

6.10	Who does maintenance of irrigation infrastructure on the scheme?	1=Farmers	2=National/ Provincial government	3=NGOs	4=Commodity group	5=Private company	6=International actor
6.11	Do you pay for water use?	1= Yes			2=No		
6.12	If yes to 5.13, how much do you pay for water monthly?						
6.13	Do you pay for electricity?	1=Yes			2=No		
6.14	If yes to 5.15, how much is the monthly cost of electricity?						
6.15	What is the state of road infrastructure in the vicinity of the scheme?	1= Very poor	2=Poor		3=Good		
6.16	What is the state of telecommunication infrastructure the vicinity of the scheme?	1= Very poor	2=Poor		3=Good		

ACCESS TO CREDIT

7.1 Have you ever **obtained a loan** in the last 5 years?

1 =YES 2=NO

7.2 If **yes,** indicate for **which needs** credit was obtained for, **when** and from **what credit source**? (List each loan separately)

Credit needs (code)	Year obtained (code)	Source of credit or Materials (2)	As Money (1)	Amount of credit	Use of credit (Code)

USE OF CREDIT CODES						SOURCE OF CREDIT CODES
Agriculture		**Business**		**Personal use**		1=State bank
Buy equipment	01	Purchase inputs and services	08	Buy food	12	2=Commercial bank
Buy livestock	02	Working capital	09	Pay medical expenses	13	3=Informal lender
Buy land	03	Purchase land/Equipment/Buildings	10	Pay school fees	14	4=Cooperative
Pay wages	04	Other business expenses	11	Pay for funeral	15	5=Savings group
Pay for services (e.g. ploughing)	05			Pass on as loan	16	6=NGO
Buy farm equipment	06			Buy furniture	17	7=Family/relatives
Buy inputs (e.g. seeds, fertiliser)	07			To pay off debt	18	
				Contribute to *stokvel*	19	
				Other (specify)	20	

7.3 If yes, was the credit received sufficient?

1=Yes 2=No

7.4 If no credit was obtained, why not? (Select code)………………………….

1 = Credit required but didn't get 2 = Credit not available 3 = Credit was too costly	4 = Lack of collateral 5 = Didn't know / not aware 6 = Fear of being unable to pay	7 = Never thought of it 8 = Does not need credit 9 = Other (specify)

INSTITUTIONAL/ORGANISATIONAL SUPPORT

NO	ITEM	RESPONSES		
8.1	Did you receive or are you receiving support from the government?	1=Yes:	2=No:	
8.2	If yes to 6.1, which government department provides support?	1= Provincial Department of Agriculture	2= Provincial Department of Land Reform and Rural Development	3= Department of Social Development

8.3	If yes to 6.1, what kind of support is provided?	1= Funding	2= Training	3= Infrastructure	4=Other (specify)
8.4	Did you receive or are you receiving support from any NGO (s)?	1=Yes		2=No	
8.5	If yes to 6.4, name the institution/organisation and indicate the kind of support? Name of NGO:______________________	1= Funding	2= Training	3=Infrastructure	4=Other (specify)
8.6	Did you receive or are you receiving support from the private sector?	1= Yes		2=No	
8.7	If yes to No 6.6, name the institution/organisation and indicate the kind of support? Name of organisation: ___________________________	1= Funding	2= Training	3= Infrastructure	4=Other (specify)

9. PSYCHOLOGICAL AND SOCIAL CAPITAL

What is the extent to which you agree or disagree with the following statements?

9.1 Psychological Capital

9.1.1 Motivation

I have plans to expand the farming enterprise.

1= Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.1.2 Confidence

I am confident in farming as a way of life.

1= Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I am confident in myself as a farmer.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I have the power to affect the outcome of my farming.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.1.3 Optimism

I am optimistic about the future of agriculture in my area.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I don't give up easily when faced with challenges.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.1.4 Risk taking

I am willing to take risks in my farming.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.1.5 Hope

I have hope that the quality of work on the farm/plot will get better.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I am willing to forgo a profit opportunity in the short run in order to benefit from potential profits in the long run.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I am willing to try new ideas even without full knowledge about the possible outcomes.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.1.6 Resilience

I am able to cope with shocks such as drought and other natural disasters.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I would not be farming if there was a better alternative source of income.

1= Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

Government is responsible for the well-being of rural households.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.2 Social capital

9.2.1 Trust

I have trust in other members of the irrigation scheme.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

I have trust in in the institutions/organization within the scheme?

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.2.2 Institutional arrangement

The current institutional arrangement on the irrigation scheme is working well.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.2.3 Existence and usefulness of social organizations

Cooperatives and/or farmers' associations are usef ul to me as a farmer/scheme

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

There are problems/issues with these organisations?

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.2.4 Existence and causes of conflict

There are conflicts within the scheme.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

9.2.5 Governance of the irrigation scheme

The governance of the scheme is working very well.

1=Strongly disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree

10. THE ROLE OF "AGENTS OF CHANGE" IN THE ADOPTION OF IRRIGATION WATER EFFICIENT TECHNOLOGIES.

NO	ITEM	RESPONSES					
10.1	How would you describe current access to the extension officers assigned to the irrigation scheme?	1=Fully accessible	2=Partially accessible	3=Not at all accessible			
10.2	In your opinion, extension and advisory services is best offered at what level?	1=Local municipal level	2=District municipal level	3=Provincial level	4=National level		
10.3	Select the top two (2) institutions that provide extension and advisory services to the beneficiaries /farmers within the scheme.	1=National government	2=NGOs	3=Commodity group/s	4=Provincial government	5=International actors	
10.4	In your opinion, what would you say is the role of change agents/extension officers in the activities of the irrigation scheme?						
10.5	Select the preferred method of technology transfer to advance learning about water efficiency irrigation technologies	1=On-field demonstrations	2=Farmer's days	3=Media (radio, TV,	4=Visits to individual farmers (no of visits)	5=Study groups a) no of groups b) no of members c) meetings, past year	6=Any other

			(number over past year)	social media)		
10.6	What is the dominant focus of extension and advisory services by the change agent?	1=Production advice	2=Market advice	3=Climate adaptation	4=Innovation technologies	5= Other
10.7	What type of digital communication tools are used for extension service provision?	1= Cellular phone	2= Laptop computer	3= Desktop computer	4= Smart pen	5= Other (specify)
10.8	What is your preferred digital tool to receive extension messages and information?	1= Cellular phone	2= Laptop computer	3= Desktop computer	4= Smart pen	5= Other (specify)
10.9	How would you describe your uptake of innovative irrigation technologies?	1= Try out new innovations as soon as you learn about them	2= Wait for few others to try new innovations before you do so yourself	3 = Try new innovations after seeing success by many others	4= Try out new innovations after everyone else has done so	
10.10	If 3 or 4 above, what would you say are the factors inhibiting adoption of new innovative irrigation technologies?		Select one (1) or more option/s √: 1= You prefer seeing success by other farmers prior to own adoption 2= You had limited access to information 3= You lacked resources required for the uptake of the innovation 4= You had concerns about the risk/s posed by the new innovation 5= Any other? Explain			
10.11	In your opinion, which stakeholder has invested the most on capacity	1= Government	2= NGOs	3= Private sector /commodity groups	4= Other commercial farmers	

	building and skills development for the farmers on the irrigation scheme?				
10.12	Did you receive any training in the past year? Yes/No	If yes, what type of training was it? Select one (1) or more option/s√: 1. Production 2. Project management 3. Irrigation technology operation 4. Marketing 5. Climate Smart Agriculture 6. Other (specify)			
10.13	Have you ever received advice or training from the extension officer on efficient irrigation water use?	1= Yes	2= No	3= If yes, specify the type of advice or training.	
10.14	In your opinion, is climate change (drought, high temps, floods) having an impact on the productivity of your farm?	1= Yes	2= No	3= If yes, a) What was the impact? b) What strategies do you use to adapt to the changing climate conditions?	
10.15	Did Covid-19 affect activities the activities on your plot/farm?	1= Yes 2=No	3= If yes, what was the effect?		

11: CHALLENGES/THREATS, OPPORTUNITIES, STRENGTHS AND WEAKNESSES

NO	ITEM	RESPONSES			
11.1	Do you experience any problem of theft on the irrigation scheme?	1=Yes		2=No	
11.2	Besides theft, do you experience any other problems?	If yes, what are the problems?			
11.3	What do you see as other opportunities for your irrigation scheme?	1= Possibility for expansion	2= Possibility for partnership	3= Other (Specify)	
11.4	What do you consider as your main strengths in farming?	1= Having contract	2=Good Infrastructure	3= Farming Knowledge	4= Other
11.5	What do you consider as your main weakness(es) in farming?	1=Lack of contract	2=Lack of good infrastructure	3= Lack of Farming Knowledge	4= Other

End of survey message:

Thank you for taking the time to participate in the survey. If you have questions, would like to see the results, or want to know more, please contact either the University of Pretoria or University of Limpopo using the same contact information as above in informed consent.