Challenges affecting the adoption of climate smart irrigation technologies by smallholder farmers in the Limpopo Province to improve sustainable productivity

CHALLENGES AFFECTING THE ADOPTION OF CLIMATE-SMART IRRIGATION TECHNOLOGIES BY SMALLHOLDER FARMERS IN THE LIMPOPO PROVINCE TO IMPROVE SUSTAINABLE PRODUCTIVITY

By

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DECLARATION 1

I, **Batizi Serote** (217192560), hereby declare the dissertation for Master of Agricultural Science at Tshwane University of Technology, hereby submitted by me, has not been submitted previously for a degree at this or any other institution, that it is my work in design and execution, and that all reference material contained therein has been duly acknowledged.

SIGNATURES

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ABSTRACT

Although the Limpopo Province is described as the breadbasket and agricultural engine of South Africa, it has been experiencing several climate-related challenges such as extreme weather conditions such as floods, heatwaves and droughts. This results in the majority of the smallholder farmers (SHF) facing frequent productivity losses because of their high dependence on rain-fed agriculture and traditional irrigation methods (TIM). Climate-smart irrigation, an important integral component of climate-smart agriculture (CSA), has been identified as one of the most suitable solutions to assist SHF in managing the effects of climate variability and change, particularly in arid semi-arid areas. However, not all have access to these technologies because of various socio-economic barriers. Adoption is often lower amongst resource poor SHF.

The main aim of this study is to investigate the challenges that SHF face in the adoption of climate-smart irrigation technologies (CSIT) to ensure sustainable productivity in the Limpopo Province, mainly focusing on the Vhembe and Capricorn districts. The unit of analysis was the individual SHF practising agriculture. Convenience and purposive sampling were used to identify 100 SHF from the two selected districts. Through one-on-one interviews, trained enumerators utilized a semi-structured questionnaire to collect information on SHF's demographics, farm characteristics and irrigation sources. The primary data collected was coded and analysed using Statistical Software for Data Science (STATA) version 15. Descriptive statistics (percentages, graphs and means) were used to analyze the challenges faced by the sampled farmers. In contrast, the Probit model was used to identify and analyse factors influencing the adoption of CSIT by SHF.

The descriptive results showed that adoption status was lower in the Vhembe district compared to the Capricorn district. The results also revealed that the challenges faced by the SHF in the two districts were related to limited knowledge and awareness, lack of financial support, insecure land tenure systems and limited access to agricultural training. Based on the descriptive analysis, it can be concluded that any change in each of the significant variables can significantly influence the probability of adopting CSIT. The results from the Probit regression model indicated that 6 out of 17 variables were significant, three at 1% (gender, household size, knowledge of CSIT) and three at 5% (district, farm size, staple food production). For the incidence of adoption level, 4 out of 17 variables were significant, one at 1% (monthly cost of water), one at 5% (household size), and three at 10% (gender, age, irrigation equipment). From the many recommendations provided in this study, the starting point should be the government providing extension officers with the required capacity, support, and physical means to expose SHF to the CSIT through demonstrations and training. The introduction of agricultural financial institutions in the rural areas would assist the rural smallholder farmer's increasing their access to credit. This will resolve most of the challenges farmers face, as adopting CSIT is often based on financial and production benefits.

Keywords: Adoption, SHF, CSIT, Probit regression model, and OLS.

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DEDICATION

I dedicate this dissertation to God the Almighty and my parents, Nomoya and Segome Serote, who have shown me nothing, but love and support. Another special dedication goes out to my daughter Relebogile Serote, you are my inspiration, and I love you, nana.

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LIST OF ACRONYMS

CSIT	CSIT
CSA	CSA
CA	Conservation agriculture
CDF	Cumulative distribution functions
ERWH	Ex-field RWH
LDARD	Limpopo Department of Agriculture and Rural Development
M&E	Monitoring and evaluation
SIS	Smallholder irrigation schemes
SHF	SHF
PPE	Personal productive equipment
RWH	RWH
IRWH	In-field RWH
TMI	Traditional methods of irrigation
OLS	Ordinary least squares

CHAPTER 1: INTRODUCTION

1.1 Background

In developing countries, climate change is emerging as the major negatively affecting agriculture and livelihoods (Kaptymer *et al.,* 2019). Mazibuko (2018) defined climate change as "fluctuations in regional and global climatic patterns, brought about mainly by human actions and is one of the most critical environmental issues. The agricultural sector and livelihoods are threatened through the occurrence of extreme weather conditions such as increased incidences of flood rates, droughts, longer dry spells, rainfall variability, and elevated air temperatures, which have resulted in low crop productivity, particularly in economically vulnerable communities (Myeni *et al.,* 2019; Mkhulani *et al.,* 2020; Williams *et al*., 2018). Marubini (2018) indicated that the crop yield is expected to be reduced by up to 50% in some countries by 2020. Therefore, most rural communities become food insecure because of the recurrent productivity losses (Mazibuko, 2018).

In South Africa, the impacts of climate change have manifested through higher temperatures, rainfall variability, and frequent droughts (Rankoana, 2020). According to Fanadzo & Ncube (2018), South Africa is categorized as the 30th driest country globally. Research has indicated that 60% of the country receives less than 500 mm of rainfall per annum, whereas 21% of the other parts receive less than 200 mm (Fanadzo & Ncube, 2018). The Limpopo Province is among the many provinces these extreme weather conditions have affected. Ubisi (2016) reported that the province has been experiencing severe droughts because of the semi-arid climate as it receives low and erratic rainfall of 400 mm. Maponya & Mpandeli (2016) indicated that the Limpopo Province was also among five provinces declared a disaster due to the current drought. The province has also been associated with the occasional occurrence of floods. These conditions are also expected to become more frequent and intense in the near future (Rankoana, 2020).

Although the province consists of a dual farming structure, the impacts are projected to be more severe amongst resource-poor smallholder farmers (SHF) because of their dependence on rain-fed agricultural production and their already vulnerable socio-economic position (Sipoko, 2014; Mkhulani *et al.,* 2020; Ubisi, 2016). Chazovachii (2016) defined SHF as farmers who own small-based plots of land on which they grow subsistence crops and one or two cash crops, relying almost exclusively on family labour. However, with SHF being at the forefront of many economies in the Limpopo Province, the farming structure needs to undergo a significant transformation as agricultural sustainability is contingent upon how farmers have employed coping and adaptation strategies toward climate change (Kom *et al.,* 2020; Maponya, 2021). It will also assist in meeting the simultaneous challenges of climate change, food insecurity, poverty, and environmental degradation (Kaptymer *et al*., 2019).

SHF has adopted climate change with traditional irrigation methods (TMI) in the past. However, there is growing recognition that TMI may be insufficient as SHF still face recurrent productivity losses due to drought and related climate hazards (Mkhulani *et al.,* 2020: Kuhl, 2019). Therefore, SHF may need to adopt improved technologies, particularly as climate change increases the speed and scale of change (Kuhl, 2019). Climate-smart irrigation technologies (CSIT) have been identified as an attractive alternative for sustainable agricultural productivity under the extreme conditions of climate change (Van Averbeke *et al.,* 2011; Phakathi, 2016). CSIT can be defined as " good irrigation practice for a given agro-climatic and societal context that takes explicit account of challenges and opportunities that may directly or indirectly from different facets of climate change" (Batchelor & Schnetzer, 2018). However, despite the availability of these technologies, existing literature has indicated that SHF is failing to manage climate variability due to the poor adoption rate of the improved agricultural technologies (Mkhulani *et al.*, 2020). The limited adoption rate of CSIT is partly attributed to various social, economic, and environmental challenges (Glatzel *et al.*, 2018; Lefore *et al.*, 2019. According to Kuhl (2019), climate change may intensify these challenges by introducing additional uncertainties regarding unknown climate impacts and unknown responses.

Over the years, the South African government has developed various strategies, such as establishing many smallholder irrigation schemes (SIS), to overcome these challenges (Fanadzo *et al.*, 2010). The main goal for developing this SIS was to ensure that the lives of populations of SHF in rural communities are improved through food security and poverty alleviation (Mnkeni, 2018). Phakathi (2016) indicated that the government made substantial investments to ensure that SHF benefited from these irrigation schemes. Unfortunately, research has revealed that most of these SIS is still underperforming despite the government's efforts, while others have collapsed (Phakathi, 2016). Therefore, adoption of CSIT remains low, and SHF continues to face low productions, which has led to high levels of food insecurity.

1.2 Research problem and justification of the study

Although the Limpopo Province has been identified as the breadbasket and agricultural engine of South Africa, the province and particularly the agricultural sector has been experiencing several climate-related challenges, such as extreme weather conditions (Lekhuleni, 2020; Musetha, 2016). Many authors have indicated that the severe drought problem experienced in the Limpopo Province did not start recently. However, these dry spells started occurring in the following years: 1981/1984, 1988/1989, 1991/92, 2004/2005, and lately in the 2014/2015 seasons (Kom *et al.,* 2020). These extreme conditions in the province have impacted SHF negatively due to their over-reliance on natural resources compounded by widespread poverty and various socio-economic, demographic challenges, poor land tenure arrangements, and unstable prices for commodities, all reducing their adaptive capacity. Due to that, efforts made by the South African government to eliminate the challenges associated with the low adoption of improved agricultural technologies have failed; ignoring such problems will further escalate poverty levels through unemployment and food insecurity.

Many authors have researched CSIT to improve water management under climate change conditions. However, not much has been published about the challenges that prevent SHF from adopting these technologies. This research study will assist in identifying the challenges that prevent SHF from adopting climate-smart irrigation systems to improve sustainable productivity. Due to that understanding, these challenges may indicate the low adoption level instead of ignoring them. Furthermore, the study's objectives will be addressed so that the findings can be implemented in other provinces experiencing facing the same challenges.

1.3 Aim and objectives

The study aims to determine challenges affecting climate-smart irrigation systems' adoption to ensure sustainable agricultural productivity of SHF in the Limpopo Province. The specific objectives are:

- To identify and analyse factors influencing the adoption of CSIT by SHF.
- To identify challenges faced by SHF in adopting CSIT to ensure sustainable agricultural productivity.

1.4 Hypothesis of the study

- Social, economic, and farming factors influence SHF to adopt CSIT.

- The low adoption rate of CSIT among SHF results from various socio-economic challenges.

1.5 The organization of the dissertation

The remainder of the thesis is organized as follows:

Chapter 1: Presents the background of the study.

Chapter 2: Presents the literature review.

Chapter 3: Presents challenges faced by SHF in adopting climate-smart technologies to improve sustainable agricultural productivity in the Limpopo Province

Chapter 4: Presents Factors influencing the adoption of CSIT for sustainable crop productivity by SHF in arid areas of South Africa.

Chapter 5: Summarises the study and discusses the significant conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter presents a review of relevant literature to understand the low adoption of CSIT among SHF. The chapter starts by defining the terms and impact of climate change on SHF. For this study, CSIT is discussed in detail, including the types of CSIT, factors to consider when selecting CSIT, benefits associated with adopting this technique, socio-economic factors influencing the adoption of CSIT, and challenges of adopting CSIT. Lastly, monitoring and evaluating CSIT concludes the chapter.

2.2. Definition of terms

Climate change

Kom *et al*. (2020) defined climate change as ‘‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods’’.

Smallholder farmers

There is no consensus or universal definition of smallholder farmers (SHF). In most cases, SHF has been defined as farmers who carry out farming activities on pieces of land of two ha or less, whereas some authors use the term to refer to farms of up to 200 ha in size (Nakawuka *et al.*, 2017). However, defining SHF only based on land size does not provide an adequate picture of the nature of SHF (Kamara *et al.*, 2019). This has resulted in other authors using attributes such as reliance on family labour, percentage of production consumed on-farm, and quantity of economic output to define SHF (Cohn *et al*., 2017; Masere, 2015). Sipoko (2014) added that some researchers have further characterized SHF by gender, race, and class. In the deep rural areas, many SHF is poor black women who practice farming mainly at a household level. For this research, SHF is defined as those farmers whose farms are characterized by low-income generation, small land utilization, lack of proper inputs, and lack of resources, limiting productivity and further increasing poverty" (Museli, 2017). However, the emphasis will be on black farmers residing in rural areas because they are most susceptible to limiting constraints.

Adoption

Adoption is when an individual or organization (Masere, 2015). Berenger (2017) defines adoption as a decision of "full use of an innovation as the best course of action available." Shange (2015) indicated that adoption involves changes in farmers' perceptions and attitudes, the progression in the acquisition of better information and farmers' ability, the progression in the acquisition of better information farmers' ability, and skill improvement in applying new technology. Adoption can also be divided into individual adoption (farm level) and aggregate adoption (Cheteni, 2014). Individual adoption refers to how new technology innovation is being used in the long run when the farmer has complete information about the new technology and its expected potential (Masere, 2015).

In contrast, aggregate adoption is when a group of individuals or farmers collectively adopts a new technology or seed variety (Cheteni, 2014). Therefore, for this particular study, adoption would refer to the favourable decisions made by SHF to practice climate-smart irrigation. Similarly, non-adoption refers to the decision not to practice climate-smart irrigation.

Irrigation

Adebayo *et al*. (2018) defined irrigation as the artificial application of water to crops that permits farming to occur in arid and semi-arid regions, particularly during periods of drought. Whereas Masere (2015) indicated that irrigation should be defined as all the different initiatives used by SHF to apply water to their crops from off-farm water sources like rivers, dams, and boreholes.

Technology

Masere (2015) defined technology as “a means of combining resources to produce the desired output.” Kuhl (2019) added that technology also includes both ‘hardware’ and ‘software,’ or knowledge and techniques required to make, use, and understand the hardware, placing knowledge, and absorptive capacity, or the ability to use external knowledge, at the centre of technology transfer. In this study, CSIT is regarded as a new technology among the target population.

2.3. Impact of climate change on SHF

SHF is the motor for rural economic growth and the welfare of the poor in most developing countries (Kom *et al.,* 2020). However, extreme weather conditions caused by climate change have a negative impact on their livelihoods. In the Limpopo Province, frequent drought due to low and erratic rainfall poses high uncertainty and agricultural production risks, leading to widespread poverty and food insecurity (Getacher *et al.,* 2013). The variable and unpredictable weather conditions that directly trigger a decline in crop yields are set to increase due to climate change, weakening the already vulnerable SHF, whose primary livelihood source is rain-fed agriculture (Ubisi, 2016; Wamalwa, 2017).

Frank & Buckley (2012) reported that despite having considerable experience dealing with climate change, the exceptional and sustained levels of variability associated with long-term climate change are outside what traditional coping strategies can manage. Farmers continue to face recurrent productivity losses (Mkuhlani *et al.,* 2020). This has resulted in some SHF moving out of the agricultural sector, particularly when faced with adverse climate change impacts (Murray *et al*., 2016). Therefore, smallholder agriculture should transform to become ‘climate-smart to prevent climate change from further exacerbating food insecurity amongst the rural communities who greatly depend on it for their livelihoods (Frank & Buckley, 2012; Kom *et al.*, 2020).

2.4. The concept of CSIT

The concept of CSIT emerged as a promising way to tackle the challenges of increasing food production and improving rural livelihoods through the adoption of effective water management in rain-fed and irrigated regions under climate change conditions (Patle *et al.*, 2019). As an essential, integral component of CSA, CSIT can be defined as ‘’ good irrigation practice for a given agro-climatic and societal context that takes explicit account of challenges and opportunities that may directly or indirectly from different facets of climate change’’ (Batchelor & Schnetzer, 2018). CSIT consists of technologies that, when implemented sustainably and locally supported, can lead to the achievement of three CSA objectives; *mitigation* of environmental damage caused by traditional agricultural practices; *adaptation* of farming methods and regimes that cope with the uncertainty and variability of climate change; and *food security* or improved agricultural production and profitability for the grower (Davidson, 2016). Proper planning and implementation of location-specific CSIT, either individually or in combination, will substantially reduce climate change impacts on water resources (Patle *et al*., 2019).

2.5. Types of CSIT

Drip irrigation

Drip irrigation is considered one of the most efficient irrigation methods. Water is saved by focusing on the root area where water is most needed and not wetting the entire soil profile

(DAFF, 2015; Lekhuleni, 2020). This irrigation method is often adopted in dry, arid regions where water is scarce and must be used sparingly (Acha, 2014). Drip irrigation is most commonly used for vegetables, orchards, vineyards, nuts, and other perennial crops (Frisvold & Bai, 2016). The water required for irrigation is delivered through plastic lateral tubes containing embedded emitters at regular spacing (Lekhuleni, 2020; Ayele, 2011). The tubes can either be laid along the ground or buried at 15-30 m and left in place throughout the production season (Acha, 2014). Although this type of irrigation system is considered more economical than the sprinkler irrigation system as surface evaporation is reduced, and yields are increased by 50-60%, the high initial cost and maintenance have been identified as the main limitations of adoption amongst SHF (Muez, 2014).

Sprinkler irrigation

Sprinkler irrigation also called overhead irrigation, imitates rainfall as water is distributed uniformly to the crops through pipes by spraying the tiny droplets of water into the air (Lekhuleni, 2020). The three main categories of sprinkler irrigation are solid-set, set-move, and moving (Msuya, 2016; Bjorneberg, 2013). It can be used for various plants, including field crops, vegetables, orchards, turf, and pastures. The spray is obtained by water flow under pressure through small orifices or nozzles, whereas the pressure is often obtained by pumping (Muez, 2014). Therefore, with a careful selection of nozzle sizes, operating pressure, and sprinkler spacing, the amount of irrigation water required to refill the crop root zone can be applied nearly uniform to suit the soil infiltration rate (Adamala, 2016). It is also considered an efficient irrigation method that requires low labour and saves time by watering a large area in one session (Lekhuleni, 2020). Unlike surface irrigation, sprinkler irrigation systems have been designed to water the field without depending on the soil surface for water conveyance or distribution (Muez, 2014). To avoid pondings and surface runoff, sprinklers are designed and arranged to apply water at a rate that does not exceed the soil's infiltration (Ayele, 2011). One of the limitations of implementing sprinkler irrigation is that the water application efficiency is usually strongly affected by environmental conditions such as wind, particularly during the daytime, when the air is warm and dry (Acha, 2014).

Mulching

Iqbal *et al.* (2020) defined mulching as "spreading various covering materials on the soil surface to minimize moisture losses and weed population and enhance crop yield." This method forms a linkage between soil and agro meteorology, which can modify the crop growing environment (Figure 2.1) (Kader *et al*., 2019). The main aim of mulching is to improve nutrient and water retention in the soil by reducing soil evaporation and preventing soil erosion by water and wind (Maphumulo, 2017; Prem *et al*., 2020). Therefore, when properly executed, mulching can significantly improve plants' well-being and reduce maintenance compared to bare soil as it suppresses weed growth (Maphumulo, 2017). Mulch is classified into organic and inorganic groups (Prem *et al*., 2020). Muttaleb (2018) and Qin *et al*. (2015) indicated that the overall efficiency and cost of the selected mulching method depends on the location, soil characteristics, crop species, and climatic conditions (rainfall and temperature). Organic mulch materials are primarily natural substances such as bark, wood chips, pine needles, dry grasses, straw, dry leaves, sawdust, and grass clipping containing organic matter (Prem *et al*., 2020; Patil *et al*., 2013). Mgolozeli *et al.* (2020) indicated that organic mulch improves soil quality, i.e., physical, chemical, and biological characteristics, by adding organic matter into the soil during the decomposition process. Due to that, some of these materials decompose rapidly, or in some instances, they may be washed/carried away by adverse weather conditions (high wind speed and high-intensity rainfall), mainly when applied in the field, it is essential to replenish them frequently (Mnkeni *et al.*, 2019; Mgolozeli *et al*., 2020).

On the other hand, inorganic mulches consist primarily of cellulose such as stones, small chips of brick, and polyethylene plastics with no significant nutrients (van der Merwe, 2012; Maphumulo, 2017; Iqbal *et al.*, 2020). These materials are mainly used to control soil erosion and moderate soil moisture and temperatures, increasing crop yield (Mgolozeli *et al.*, 2020). Therefore, it is essential to use them with understanding because, unlike organic mulches, they do not improve soil structure, add organic materials, or provide nutrients (Mnkeni *et al.*, 2019).

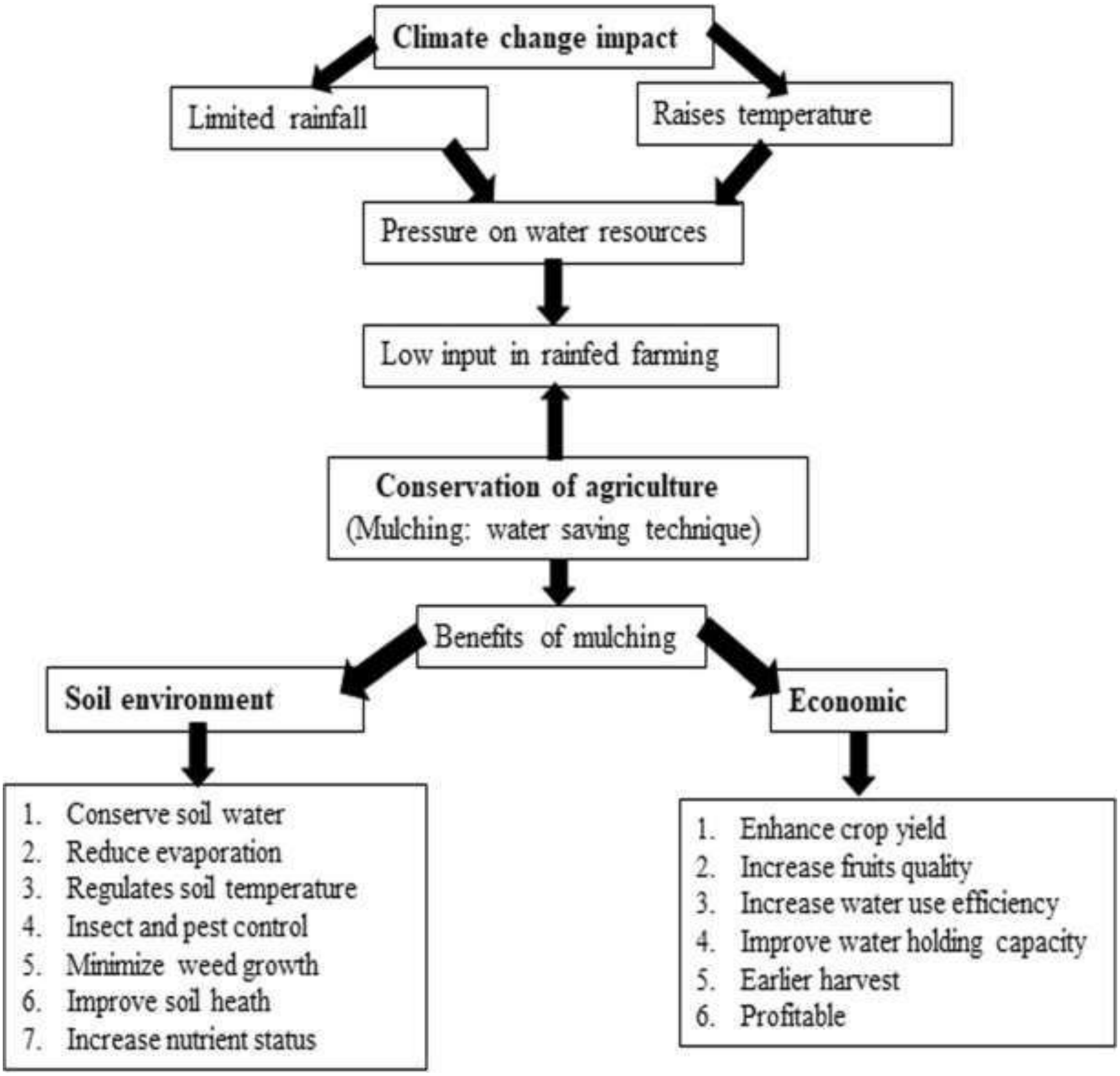

Figure 2-1: Schematic diagram indicating the interaction between mulching, climate change, and crop production. Source: Kader et al. (2019).

Rainwater harvesting technologies (RWH)

The Limpopo Province, particularly the Vhembe district, tends to experience periods of heavy rainfall. During these times, water flows unimpeded, flooding low-lying areas, blocking roads, and washing away bridges. Therefore, due to the high dependency of SHF on rain, there is a need to optimize rainwater productivity to increase agricultural yields and improve rural livelihoods. According to McCosh *et al*. (2017), RWH is defined as the process of concentrating rainfall as runoff from a larger catchment area for its productive use in a smaller target area. The collected runoff can be applied either directly to an agricultural field for crop production or be stored in some storage facility for domestic use and supplemental irrigation (Botha *et al.,* 2014). The process can take place naturally or artificially. Ojwang *et al.* (2017) indicated that this technique is suitable for arid and semi-arid areas that experience unpredictable rainfall, recurrent droughts, and heavy torrents and floods when it rains. Therefore, RWH has been identified as the only alternative for accessing sustainable quantities of water to satisfy crop requirements during periods of drought (FAO, 2014).

Classification of RWH technologies

RWH can be classified as (1) Micro-catchment (in-field RWH, IRWH), (2) Macro-catchment (ex-field RWH, ERWH), and (3) Roof-top micro-catchment (non-field RWH, RRWH).

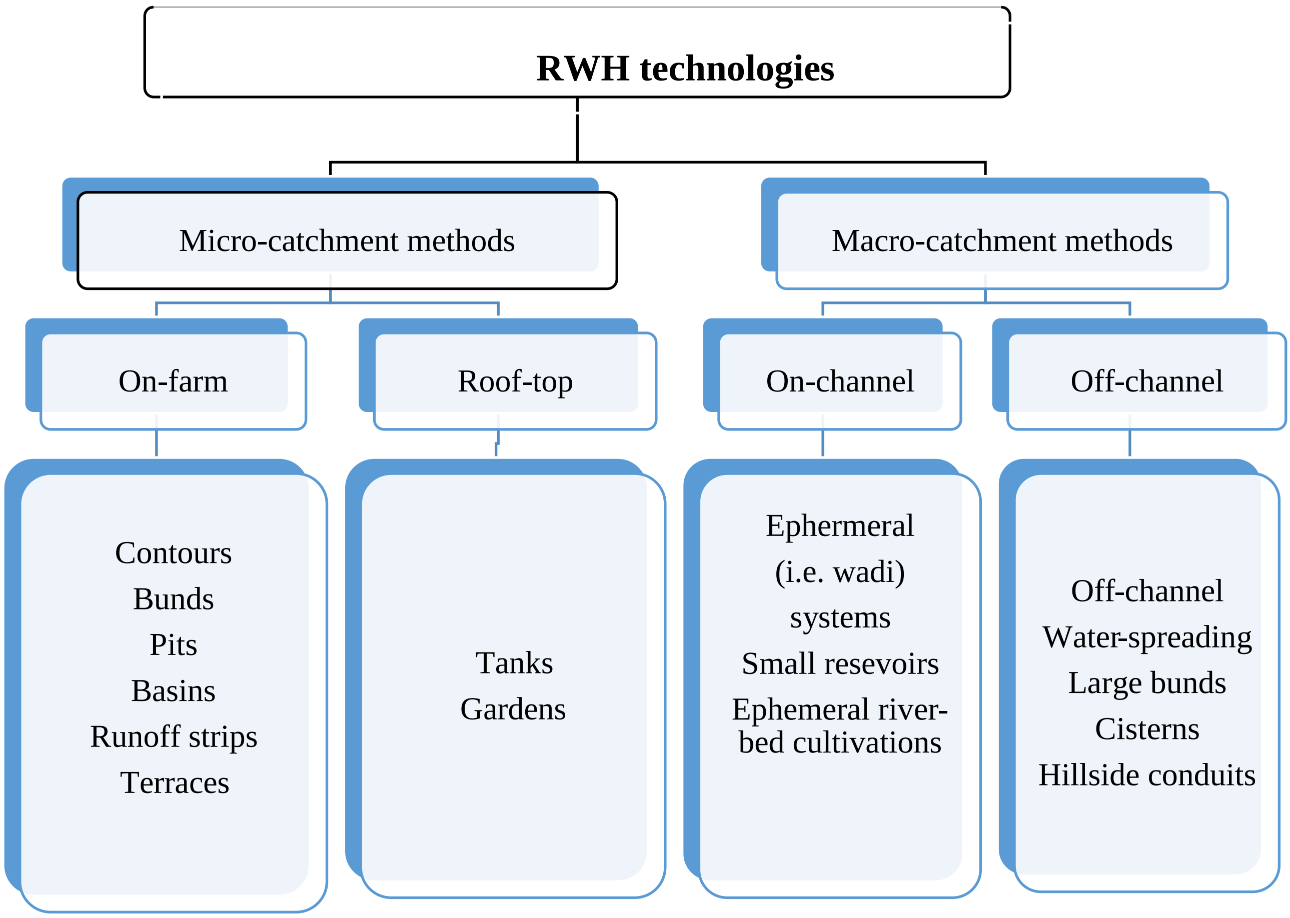

Figure 2-2: RWH methods. Source: McCosh *et al.* (2017)

In-field RWH (IRWH)

In-field RWH (IRWH), which can also be referred to as micro-catchment (Table 2. 1), involves the collection of surface runoff from small catchments of short length (Mnkeni *et al.*, 2019). The collected runoff water is stored in basins, usually with the assistance of mulch and other forms of water conservation to facilitate enhanced infiltration directly in the soil profile, and there is no provision for the overflow of excess water (Tesfuhuney *et al.*, 2020; McCosh *et al.*, 2017). The primary purpose of this technique is to reduce soil erosion and improve rainfall infiltration and conservation in the soil profile (Kiggundu *et al.*, 2018). Rooftop RWH is another essential micro-catchment system used primarily for domestic purposes. However, it can be used for small-scale irrigation and livestock watering (McCosh *et al.*, 2017). Ojwang *et* *al.* (2017) reported that the quantity and quality of the harvested rainwater greatly depend on the type of roofing material used. For instance, hard surfaces such as iron sheets, asbestos sheets, and tiles produce the highest amount of collected water because they have high runoff coefficients (Ojwang *et al*., 2017; Shange, 2015). The collected water is usually diverted to a storage tank or containers of all types (Shange, 2015; Botha *et al*., 2012).

Table 2-1: Micro-catchment systems

Type of the Micro-catchment systems	**Description**
Pitting (*Zai* pits, *Ngoro* pits, trenches, *tassa* pits, etc.).	*Zai* pits: A grid of planting pits is dug across plots that could be less permeable or rock-hard; organic matter is sometimes added to the bottom of the pits. *Ngoro* pits: A series of regular traditional pits, 1.5 m square by 0.1–0.5 m deep, with the crops grown on the ridges around the pits; Trenches: pits are made along the contour, sometimes with a bund downslope, either staggered or continuous, to check the velocity of runoff, conserve moisture and increase groundwater recharge.
Contouring (Stone/soil bunds, hedge-rows, vegetation barriers)	Require frequent tillage at the beginning to be applied. Stone and soil bunds: A stone or sometimes earthen bank of 0.50–0.75 cm height is piled on a foundation along the contour in a cultivated hillslope, sometimes stabilized with grasses or other fodder plant species. Hedgerows: Within individual cropland plots, strips of land are marked out on the contour

	and left unploughed to form permanent, cross-slope barriers of naturally established grasses and herbs. Alternatively, shrubs are planted along the contour. The main aim of these methods is to reduce runoff and increase infiltration rate and soil water storage
Terracing (*Fanya Juu*, Semicircular and hillside terraces)	Bunds associated with a ditch, along the contour or on a gentle lateral gradient, are constructed differently. The *Fanya Juu* terraces are different from many other terrace types in that the barrier is put in the upslope position.
Micro-basins (Negarims, half-moons, and eyebrows)	It aims to retain water in situ or slow down the runoff water velocity. Different shapes of small basins, surrounded by low earth bunds, are formed to enable the runoff to infiltrate at the lowest point, where the plants are grown. The differences between the different structures are basically in their shapes, Negarims (diamond), Halfmoon (Semi-circular), etc.

Source: Biazin *et al*. (2012)

Ex-field RWH (ERWH)

Ex-field RWH or macro-catchment (Table 2.2) involves collecting runoff from large areas at an appreciable distance from where it is being used (Tolossa *et al.*, 2020). The runoff is usually collected from existing paved surfaces and natural slopes, and to a lesser extent, from intended built-up structures (Temesgen, 2012). McCosh *et al.* (2017) and De Trincheia *et al*. (2016) indicated that the generated water could be placed in fields and stored in the soil profile, ponds, tanks, and aquifers for further use during the dry season.

Table 2-2: Macro-catchment systems

Type	Description
Traditional open Ponds	Runoff collected from cultivated hill slopes, natural watercourses, footpaths, or cattle tracks is stored in un-plastered and open ponds. The stored water usually suffers from losses due to seepage and evaporation.
Cisterns	Runoff collected from bare lands, cultivated hill slopes, or road catchments is guided and stored in underground storage tanks. The cisterns have plastered walls and covered surfaces. In most cases, settling basins are attached to the inlet to reduce sedimentation; otherwise, regular cleaning is required.
Earthen dams (Micro-dams)	Larger-sized rainwater storage systems such as (ndivas) in Tanzania and micro-dams in Ethiopia are communally constructed around the foot of hill slopes to store the runoff from ephemeral or perennial rivers. The reservoirs are neither plastered on their walls nor covered on their surfaces. The water is mainly used for supplemental irrigation communally and for cattle.
Sand dams	Dams are constructed to store part of the natural flow in seasonal rivers. The sand carried by the river will settle upstream of the dam and gradually fill the streambed. Hence, the sand will reduce evaporation and contamination of the water in the sand body behind the dam.
Ephemeral stream diversions and spate irrigation	Ephemeral streams from uplands are diverted from their beds (*Wadis*) at the *agim* (temporary diversion structure) to irrigate adjacent crop fields downstream, usually before planting.

Source: Kiggundu *et al.* (2018) and Mnkeni *et al*. (2019)

Complimentary water conservation methods

McCosh *et al*. (2017) reported that the application of RWH as a method for improving water management is often not sufficient by itself and should be used in combination with other water conservation methods. Unlike RWH, these methods generally do not need a runoff-inducing catchment area instead, they aim at enhancing rainfall infiltration and reducing soil evaporation to achieve better yields where soil moisture is a constraint (Temesgen, 2012; De Trincheia *et al*., 2016).

Table 2-3: Water conservation methods.

Type of structure	Description
Ridging	Using a modified ploughing instrument, basins more expansive than traditional furrows are created either by manual hoeing or during tillage. They can be designed to be tied every 3-6 m distance for holding water and facilitating infiltration in low and erratic rainfall areas.
Mulching	Crop residues, and material from non-cultivated areas, including stones, cover the soil. This improves water infiltration into the soil and prevents evaporation out of the soil.
Furrowing and pot-hoeing	Different furrowing techniques are used before and after planting to conserve soil moisture in areas where oxen

	ploughing and hand-hoeing are common. In the Sahel, small shallow holes are dug manually at correct intervals, and the seeds are covered with soil; Two weeks after the crop's emergence, they add fertilizer about 10 cm from the plant.
Conservation tillage	It encompasses various tillage techniques ranging from noninversion ploughing and reduced tillage to ripping and subsoiling in sub-Saharan Africa.

Source: Biazin *et al*. (2012) and McCosh *et al*. (2017)

2.6. Factors to consider when selecting CSIT

Before adopting CSIT, SHF needs to consider several important factors to evaluate if the selected technology suits their situation. The factors that need to be considered before CSIT are selected have been discussed below.

2.6.1 Economic factors

Capital investment

Before selecting an irrigation system, farmers should do a benefit-cost analysis that rigorously assesses the system's economic viability. Construction, installation, operation, and maintenance costs should be considered instead of the expected benefits and return on investment. A correct decision would always be to select an intelligent system in cost input and output (Oteng-Darko *et al*., 2019). According to Steven & Buys (2012), micro-irrigation systems are generally more expensive per hectare than portable irrigation systems. Due to economic reasons, farmers would instead select the cheaper portable system, although it might not be ideal for the specific situation (Reinders, 2013). This has resulted in some suggesting that adopting efficient irrigation systems is typically not motivated by water conservation but rather through potential economic gains of increased crop yield (Stubbs, 2016).

Cost Items

Maintenance

This involves the lubricants, spare parts, and the additional equipment available on the farm to carry out replacements and repairs (Stevens & Buys, 2012).

Labour

This involves the workers responsible for all aspects of the operation and the maintenance of the system (Stevens & Buys, 2012).

Energy/operating costs

Sprinkler systems such as big guns, travelling guns, and high-pressure travelling boom often have higher energy requirements and operating costs than low-pressure systems such as drip irrigation (Reinders, 2013). This should be taken into consideration when it comes to system selection.

The expected life span of the system

This factor is essential when the system has been bought through loans to determine the financing period. It also determines the replacement period of a system. In most cases, average values are used, and banks work very conservatively when lending money for such assets. Careful operation and maintenance would result in a life span that is far greater than the financing period. Therefore, enabling farmers to spend the money on other equipment or expand operations (Stevens & Buys, 2012).

2.6.2 The efficiency of the irrigation system

Reinders (2010) reported that when the irrigation system efficiency value is considered during the planning of irrigation systems, it makes provision for losses that may occur between the inflow to the irrigation system and the point where the irrigation water is available to the crop root zone. For instance, sprinkler irrigation efficiency can be affected by water loss via evaporation of droplets in the air and moved by wind (Eudoxie *et al.*, 2020). Losses may also include filter backflush, in-field conveyance losses, and other possible minor losses. Therefore, according to the equipment manufacturers' and irrigation designers' recommendations (Reinders, 2010).

Viability of irrigation development

A conservative approach would be advisable when planning an irrigation development, calculating operating and profit margins. It should be taken into account that the SHF involved may be in a learning phase regarding irrigation management, crop cultivation, and marketing. Thus, the cost of irrigation systems, inputs, energy, and maintenance can result in smallholder irrigation development being cost-inefficient, particularly for SHF. The repayment of an irrigation system is highly dependent on profitable crop production (Stevens & Buys, 2012).

2.6.3 Institutional factors

Labour and supervision

Labour requirements will always be a factor in the choice of system. CSIT, such as drip irrigation systems, often require a high level of technical knowledge and less labour than traditional systems (Stubbs, 2016). However, other techniques such as RWH have high labour requirements at all stages, from construction and operation to maintenance (Shange, 2015). Therefore, a shortage of skilled labour or cost of labour results in a low adoption rate.

Availability of support services (extension, technical, etc.)

Extension officers are necessary when farmers seek to use CSIT, looking at well-established companies and brand names with adequate service backup and spare parts (Stevens & Buys, 2012). They would assist in providing support for institutional mechanisms designed to support the dissemination and diffusion of knowledge among farmers and demonstrate gains from new technologies (Wekesa, 2017). Farmers should also be trained on routine maintenance, troubleshooting, or repairing the technology, which is not intensively given (Nakawuka *et al.*, 2017). This particular support often results in farmers adopting CSIT if advisors are available to them regularly.

Maintenance and operation requirements of the system

Most irrigation systems become inefficient or useless due to the lack of maintenance (Stevens & Buys, 2012). Although system maintenance can be an easy process, extension officers often fail to train farmers on routine maintenance, troubleshooting, or repairing the technology (Nakawuka *et al.*, 2017). However, in some cases, farmers are guilty of not following the well laid-out maintenance plan implemented by extension officers. A well-laid-out maintenance plan could indicate the following: all pump systems should be lubricated for the bearings to run smoothly and stay cool; when drip irrigation systems are being used, the proper flushing and cleaning procedures should be used to prevent blockages; servicing schedules which include an inventory and spares in stock to be kept and replacement schedules for different components (Dukes *et al*., 2018; Reinders, 2010). When an irrigation system is well maintained, it performs well in terms of efficiency and consistency, requires few emergency repairs, and helps the producer optimize their crop production system, maximizing profits (Reinders, 2010).

However, failure to follow a well-laid maintenance plan will result in the system needing to be replaced prematurely.

2.7. Socio-economic factors influencing the adoption of CSIT

Socio-economic factors are often associated with decision-making in the adoption of agricultural technologies. However, the pattern of influence of these factors is context-specific, depending on location and the technologies evaluated (Kurgat *et al.*, 2013). In efforts to scale up the adoption of CSIT in the Limpopo Province, it is critical to understand how socioeconomic factors affect the adoption of agricultural innovations across diverse contexts.

This section reviews socio-economic factors such as age, gender, educational level, household size, land size, and farmers' perception.

Age

Age is a factor that is often considered when determining the SHFs' willingness to adopt agricultural technologies. According to Shange (2015), existing literature has put forward contrasting arguments on how age affects the adoption of agricultural technologies. Masela (2017) and Nkonki-Mandleni *et al.* (2018) indicated that young people are often more adaptable and enthusiastic about trying new technologies than the older generation, who are traditionalists and very conservative to change. Contrary to this, Kom *et al.* (2020) and Maponya (2021) argues that in both the Vhembe and Capricorn district, a significant proportion of the SHF was above the age of 40 years. The possible explanation could be that older farmers often possess the required experience and social capital to become critical players in the system (Abegunde *et al.*, 2019). The younger generation had no interest in the agricultural sector and viewed it as an occupation fit for only the older generation that could not generate enough income to sustain their livelihoods (Musetha, 2016). However, the dominance of old-aged farmers raises critical questions about the future of smallholder irrigation. As farmers get older, they tend to lose energy, have short planning horizons, and become risk-averse (Fanadzo & Ncube, 2018; Mango *et al.*, 2018). Therefore, despite their accumulated experience in farming, adopting new technologies may be complicated for them (Mango *et al*., 2018). McCosh *et al.* (2017) concluded that age does not influence the adoption of agricultural technologies, but the importance of growing food will be a greater driver of adoption.

Gender

Wekesa (2017) and Jha *et al.* (2019) found that the effect of gender on adoption decisions is location-specific and culture-driven. For instance, in some parts of Kenya, women who want to adopt CSA should obtain permission from male relatives (James *et al.*, 2015). Whereas, in some rural parts of the Limpopo Province, women, who are often the actual farmers, find themselves in a situation whereby the title deeds of their lands are in the names of men, thus creating disincentives to farming (Fanadzo & Ncube, 2018). These situations result from traditional power structures, and control over productive household resources is less favourable towards women. This results in them responding less positively to new technology than in male-headed households (Esabu & Ngwenya, 2019).

Esabu & Ngwenya (2019) indicated that although women have less access to crucial farm resources, some studies reported more likely to adopt climate change adaptation strategies than their counterparts. This is consistent with the findings of Kom *et al.* (2020), who indicate that in the Limpopo Province, females comprised most of the SHF. The possible explanation for this observation is that women dominate most rural smallholder farming communities, whereas males are more likely to relocate to nearby cities for job opportunities to diversify income sources (Wekesa, 2017; Kom *et al.*, 2020; Masela, 2017). Therefore, in this context, women have more farming experience and information on various management practices and how to change them, based on available information on climatic conditions and other factors such as markets and food needs (Okumu, 2013). On the other hand, Masela (2017) reported gender has no influence on technology adoption as males and females are likely to play different roles depending on the nature of the technology. Ndlovu *et al.* (2020) reported that due to the labour demanding nature of in-field RWH techniques, most female-headed households in Zimbabwe indicated a challenge in adopting these techniques. Mwangi & Kariuki (2015) concluded that an SHF's decision to adopt a particular technology depends primarily on access to resources rather than on gender.

Household size

The influence of household size in the decision-making process of adopting agricultural technologies can be two-sided. Large household sizes often result in cheap labour availability, thus positively influencing the adoption of new technology as the labour constraints would be reduced (Wekesa, 2017; Rapholo, 2018). Shange (2015) reported that family labour positively influenced the adoption of IRWH technology and the likelihood of food security amongst SHF in the Limpopo Province. However, smallholder irrigation can only absorb a certain amount of labour, and increase household sizes to reduce labour returns (Sinyolo, 2013). Some family members may decide to look for other opportunities with higher returns for their labour to reduce consumption pressure caused by large household sizes (Sinyolo, 2013, Kom *et al*., 2020).

Land size

According to Shange (2015), land size can have different effects on the probability of adoption, depending on the characteristics of the technology and the institutional setting. Lebeta (2017) and Shaw (2014) indicated that farmers who cultivate large farms are more likely to adopt CSIT than their counterparts because they can afford to devote only a part of their land to the new technology. In Ethiopia, SHF with large farm sizes constructed a rainwater-harvesting pond, which can be difficult to construct on smaller plots (Mengistu, 2021).

Although farm size indicates wealth and social status in some communities, this is not always the case in rural areas where resource-poor SHF dominates. Therefore, a serious limitation of cultivating large crop sizes would be the significant investment in labour and inputs (Selejio & Lasway, 2019; Myeni & Moeletsi, 2020). Farmers who cultivate small land sizes will likely adopt new technologies to maximize their small farm plots (Mangisoni *et al*., 2019). However, existing literature indicated that the relationship between farm size and adoption depends on fixed adoption costs, risk preferences, human capital, credit constraints, labour requirements, tenure agreements, and so on (Shaw, 2014). Mwangi & Kariuki (2015) concluded that technology adoption concerning land size could be explained best by measuring the total land area suitable for the new technology.

Education level of the SHF

The level of education is another vital factor related to the adoption of CSIT because it is assumed that literate farmers are in a better position to learn about new technologies and use them to contribute positively to the outcomes of their farm production (Mangisoni *et al*., 2019). Msuya (2016) indicated that SHF with at least a primary school level of education has a higher probability of adopting drip irrigation than non-educated ones. The literate farmers would also be able to assist fellow farmers with advice and information regarding the adoption of CSIT (Sani, 2017). This would be very helpful in areas whereby the presence of extension officers is limited.

On the contrary, some researchers have indicated that education has an insignificant or negative effect on technology adoption. However, Wekesa (2017) reported that higher educational attainment could limit adoption because it offers alternative livelihood strategies to compete with agricultural production (Okumu, 2013). In contrast, Ulrike (2018) revealed that education had no significant effect on adopting agricultural technologies. The level of education, in general, does not necessarily translate into the level of agricultural knowledge, as the formal education from school or university covers only a few agricultural aspects. Therefore, most farmers, particularly in the rural areas, obtain their farming knowledge from the previous generations or through self-study. That empirical evidence has reported mixed results on the influence of education and the adoption of new technology, and more studies should be done to come up with more consistent results (Mwangi & Kariuki, 2015).

Farmers' perception of the CSIT

Farmers' perceptions of CSIT also play a significant role in adoption. Due to that, CSIT contradicts much of the knowledge on traditional irrigation; it could be difficult to convince farmers to adopt CSIT if they do not experience environmental solid or economic pressures to change (James *et al.,* 2015). Nkonki-Mandleni *et al*. (2018) revealed that farmers' perception is often based on economic reasons. According to Msuya (2016), farmers' perceptions of whether drip irrigation is affordable for SHF indicate that farmers still believe in improved technologies to expand production, productivity, and overall income. Cheteni (2014) indicated that direct costs and profits associated with improved agricultural technology affected farmers' perceptions.

In contrast, a study by Ndlovu *et al.* (2020) offered a different opinion regarding farmers' perception of the adoption of CSIT, such as RWH techniques. The findings revealed that some farmers believed that in-field RWH techniques were strenuous and labour intensive but with little or no benefit. Thus, improved agricultural technologies require substantial changes in practices and mindset, particularly in areas where most SHF still use TIM.

In addition, the farmers' perception of the technologies advantages and constraints may depend on the characteristics of the potential users (literacy and low technical capacity of farmers) but also on the actions and features of the suppliers of the new technology (inappropriateness of the technology), as well as on the interactions between users and suppliers and on the regulatory environment (lack of information about the technology) (Ouédraogo *et al.*, 2019). Therefore, it can be concluded that farmers' perceptions differ in adoption, and no apparent factor can be generalized to each new technology (Cheteni, 2014).

2.8. Benefits associated with the adoption of CSIT

Many authors have indicated that the use of CSIT resulted in more benefits than TMI (Traditional methods of irrigation. Shange (2015) assessed the socio-economic factors that influenced the adoption of IRWH technology for enhancing household food security by SHF in Nkonkobe municipality in the Eastern Cape and maintained that benefits such as an increase in production yield and generation of income improving food security could be achieved through IRWH technique. Whereas, a study by Kumar (2012) pointed out that an analysis of the economics of crop cultivation under drip and flood methods revealed that the drip method of irrigation has a significant impact on resources saving, cost of cultivation, and the yield of crops, and farm profitability. Alaofe` *et al*. (2016) added that agricultural interventions such as

CSIT could reduce poverty, build resilience to climate change and improve food security. Below are the benefits that this section focuses on.

Improving food security

Many researchers throughout the years have defined food security. Masipa (2017) defined food security as the ability of individuals to obtain sufficient food on a day-to-day basis. Oyawole *et al.* (2020) indicated that food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." Muez (2014) added that the definition contains different features: food availability, accessibility, utilization, and stability. According to Shange (2015), in the past, household food security was based on an assessment of food supply; therefore, a decrease in the food supply would be regarded as the only cause of household food insecurity. However, more recent views stated that food security is the outcome of many interrelated factors: water, an essential resource for food production (Maponya, 2019).

In the context of this study, the definition of food security by Oyawole *et al*. (2020) was adapted. RWH technology has been identified as one of the most promising technologies to combat food insecurity, particularly in arid and semi-arid areas (Mengistu, 2021). A study by Shange (2015) indicated that a research project conducted in the EC revealed that 96% of project members felt better off since the introduction of the IRWH technology. It has enabled them to afford three to four meals a day, which was not the case in the past. Mekuria *et al.* (2020) also argued that the adoption of RWH ponds improved household daily calorie intake per adult equivalent by 359.27 kilocalories, which is higher by 15.56% than non-adopters. This concurs with Wachira (2013) results, which indicated that the adoption of ponds had improved the livelihoods of the communities through increased food and water security.

According to Chidavaenzi *et al.* (2021), drip irrigation has been identified as the key to alleviating a significant share of rural hunger and poverty in low-income communities. In Zimbabwe, the poorest households produced a minimum of 30 kg of cereal before drip intervention compared to 100 kg per annum with drip intervention. Paza *et al*. (2018) added that micro-irrigation technologies such as drip and sprinklers are becoming popular and received support from various government departments, the private sector, and NGOs to increase food and nutritional security. Assefa *et al.* (2019) investigated the experimental evaluation of conservation agriculture with drip irrigation for water productivity in Sub-Saharan Africa. The results indicated that using conservation agriculture (CA) such as grass crop residue with drip irrigation had the potential to increase food supply and sustain the livelihood of SHF in Sub-Saharan Africa (Assefa *et al.,* 2019).

Improving nutritional status

According to Shange (2015), at an SHF level, the adoption of IRWH techniques has resulted in improved productivity growth hence, increasing rural income and food availability, thus enabling improvements in their diet as concluded by the study by Wachira (2013) on impacting assessment of RWH ponds in Ethiopia. Shange (2015) added that the results of the IRWH project in the Eastern Cape indicated that the adoption of IRWH technology had the potential to address nutritional problems in rural areas. The project members grew a wide range of crops such as maize, beans, cabbage, carrot, tomatoes, beetroot, spinach, and new vegetables such as cauliflower, broccoli and turnips green pepper helped to improve their quality of diet. Similarly, Alaofe` *et al.* (2016) reported that using a solar-powered drip irrigation system offered farmers the possibility of diversification of crop production into higher-valued and nutritious fruits and vegetable crops. Assefa *et al*. (2019) further indicated that improved yields obtained through

CA with the drip irrigation systems enabled farmers to use a portion of their vegetables for household consumption, thus addressing any malnourishment challenges in the region. While in the Limpopo Province, it was identified that SHF who were part of an irrigation scheme whereby CSIT such as drip and sprinkler irrigation systems were used attained household and individuals' nutritional security (Mwadzingeni *et al*., 2020).

Increased production yield

Msuya (2016) investigated the difference in vegetable yields associated with traditional surface irrigation and drip irrigation. The results of the on-farm trials revealed that crop yields more than doubled using drip irrigation, to which good management practices were applied. Msuya (2016) added that the difference in yield under the two irrigation methods might have resulted from the fact that most soil nutrients were washed away during flooding, thus having long-term adverse effects on the yield unless those nutrients are replenished. Yavuz & Suheri (2012) reported that the drip irrigation method's potato yield and quality parameters were better than those collected in sprinkler and furrow irrigation methods. Nairizi (2017) highlighted that sprinklers on row crops resulted in 33 and 37% higher yields than the basin and broader strip irrigation methods.

Assefa *et al.* (2019) indicated that adopting CA and drip irrigation could improve crop yields. This is consistent with the findings of Xiaoping & Chen (2015), whose study results reported that the average maize yield was 15000 kg/ha when using drip irrigation under plastic film, while the average maize yield is 7,500 kg/ha using ordinary planting and irrigation. Paza *et al*. (2018) concluded that yield improvements from micro-irrigation technologies rely on the crops grown, soil type, and irrigation technology used.

Wachira (2013) reported that RWH technologies which have been tested and found to be suitable for increasing crop productivity are those able to retain rainwater in-situ in the farms for crops (tied and open ridges) or those that allow rainwater to be retained on open furrows for longer duration as the water infiltrates the soil. For instance, maize yields from 2.18 to 2.43 ton/ha in eastern Kenya using tied ridges. James *et al.* (2015) added that stone bunds constructed along contours combined with Zai pit filled with composts or manure had increased sorghum and millet yields of up to 1t/hectare over unimproved land in Burkina Faso. Shange (2015) assessed the agronomic sustainability of the IRWH technique in South Africa. The results concluded that the IRWH technique contributed to higher crop yields than normal conventional tillage because it stops run-off and minimizes soil evaporation losses. In addition, research conducted by ARC (Agricultural Research Council) and its partners at ThabaNchu indicated that adopting the IRWH technique led to maize yields increasing by up to 50% compared with conventional production techniques (Shange, 2015).

Income generation

A Water Research Commission-funded project on IRWH technology for homestead backyard gardens in South Africa revealed that profitability analyses using enterprise budgets showed that farmers who adopt even the simplest form of in-field RWH compared to conventional crop cultivation could increase their income by about R800 per hectare in the case of maize production (Badisa, 2011). Alaofe` *et al.* (2016) reported that the increased income received from the adoption of a drip irrigation system powered by solar energy might assist farmers in being more resilient and increase their absorptive capacity during times of economic difficulty or a natural disaster such as high food prices or recurrent climate shocks. In Ethiopia, using a drip irrigation system has increased income and production diversity; therefore, it can be concluded that increased income leads to improved diets (Passarelli *et al.,* 2018).

Narayanamoorthy *et al.* (2018) added that evidence that has been provided on the reduction in labour costs and yield advantages indicates that the drip irrigation system is technically and economically superior to flood irrigation. Khalifa *et al.* (2020) revealed that a benefit-cost analysis indicated that the entire capital cost was recovered from the first year's income, even without subsidy. In addition, the use of locally produced organic mulch such as wood debris to rehabilitate damaged lands would increase farmers' income and enhance crop growth and development (Iqbal *et al.*, 2020).

2.9. Challenges of adopting CSIT

Despite the benefits that could be gained from CSIT, its adoption, particularly among SHF, remains low. This is because several challenges prevent SHF from adopting CSIT, and so far, existing policies and actions to remove these barriers remain inadequate. A good understanding of these challenges and how they prevent adoption is essential. Below is a discussion of some challenges often faced by SHF.

Land tenure security

Insecure land tenure has been a constraint for SHF for the past decade. The related constraints include inequitable access to land and a sound system of land rights transfer, resulting in underdeveloped agriculture and degraded natural resources (Masere, 2015; Museli, 2017). According to James *et al*. (2015), the land is controlled through traditional tenure systems governed by decision-making authorities at the family, clan, chief, or village level in most rural areas. However, such land tenure systems have resulted in land distribution that creates social divisions and conflicts based on class gender (Lekhuleni, 2017). For instance, women in South Africa can only acquire rights to land through marriage (Museli, 2017). Whereas, in Swaziland, for a single woman to own land, the male child is used to acquire a Swazi Nation Land (SNL), which is similar to a Permission-to-Occupy (PTO) that is used in South Africa (Shabangu, 2016). This implies that even though a woman may be responsible for over 60% of the farming activity in the smallholder irrigation sector, mainly men (Sinyolo, 2013) will still make decisions. In addition, some property owners may not feel secure enough to lease out land for fear of losing it and prefer to take it out of production, resulting in large tracts of land lying fallow (Fanadzo & Ncube, 2018). Insecure land tenure systems will continue to create uncertainty in the prospects of young farmers who would have committed resources to make a living from the practice of irrigation Fanadzo & Ncube, 2018). SHF in South Africa continued to produce in the face of unfavourable conditions created by the Land Act of 1913 that excluded them from owning land (Mzuyanda, 2017). While international businesses continue to buy productive land across the developing world, displacing small-scale farmers (Shabangu, 2016). Therefore, for farmers to adopt CSIT, they should have ownership rights that enable them to sell or rent their land and that their children can inherit the land (Sinyolo, 2013).

Inadequate labour

In the form of scarce labour, poor supervision of labour and family responsibilities was identified as a key challenge that influences decisions in most smallholder production systems such as adopting CSIT (Murray *et al*., 2016; Kaptymer *et al.*, 2019). James *et al*. (2015) indicated that although the adoption of CSIT is expected to reduce labour requirements in the long term, in the short term, it is quite common for CSIT to require increased labour, particularly for activities such as weeding and land preparation. Whereas family responsibilities can become a challenge to labour as most members may be required to do other income-generating activities to meet their immediate needs (Zighe, 2016). Therefore, this would affect their level of adoption as CSIT requires a reasonable amount of time (Zighe, 2016).

Lack of Market

When SHF has limited access to market infrastructure, it becomes challenging for them to shift from using TMI, as they would have no reason to produce more than they can consume. Participation in the market is often meant to have a positive impact on the income, thus enabling SHF to adopt CSIT; however, in most cases, farmers are often located in remote areas whereby the road infrastructure is underdeveloped, links to markets are limited, and the value chain actors are non-existent (Fanadzo & Ncube, 2019). A study by Jiyane & Simaleng (2019) indicated that in the Vhembe district, SHF often does not make prior arrangements of markets for the vegetables grown, resulting in produce fetching low prices. In such areas, farmers lack price, supply and demand, and quality standards, thus facing higher prices from opportunistic intermediaries and traders and lower market participation (Paloma *et al*., 2020). Therefore, SHF will continue to be trapped in poverty with surplus production (von Loeper *et al*., 2016).

2.10. Monitoring and evaluation of CSIT performance

Successful adoption of CSIT being tested during on-farm trials requires regular feedback from monitoring and evaluation (M&E) systems. It is essential to learn from success and failure to develop best-practice during the adoption process (Thomas *et al.*, 2017). The M&E systems should consistently be implemented at the beginning of the project to assess the adopted technologies' efficiency and effectiveness (Mnkeni *et al.*, 2019). It is also important to note that monitoring and evaluation are not entirely separable, although they are two different activities. Monitoring deals with tracking the progress and intermediate results of the project and making adjustments during the project’s implementation. In comparison, evaluation assesses results and effects (Kanamaru & Hancock, 2013). Therefore, to understand the causes and effects of different actions, these two should be linked (Kanamaru & Hancock, 2013).

In addition, early definition of project objectives, identification of sound performance indicators, and precise reporting requirements are essential to effective M&E systems as they would assist in tracking the changes during on-farm trials(Swanson & Rajalahti, 2010). For instance, in measuring the impacts of IRWH, farmer groups may use the following indicators: yield per hectare parameters such as number and size of fruit, plant height, the colour of leaves, number of leaves, number and size of maize cobs, the survival rate of seedlings, days spent working on the trial, cost of labour, income from selling plot produce, the temperature of the soil, signs of erosion, soil moisture, root penetration in the soil and soil resistance to penetration by a knife or stick (Mnkeni *et al.*, 2019). However, the actual selection of indicators usually depends on the kind of information the group desires and how they want to measure change. Furthermore, selecting a good indicator also requires experience and skill that SHF can obtain through the assistance of extension services (Mnkeni *et al*., 2019).

2.11. Summary

The adoption of CSIT is not a once-off decision, and it is a stepwise decision made after carefully weighing opportunity costs at each point. Amongst those would be the socioeconomic factors and institutional factors. However, adoption can be limited by challenges that can limit the adoption by SHF. Unfortunately, most of them are resource-poor and unable to adapt to climate change will worsen their vulnerable conditions. Although many studies have been done on CSIT, most focused on the drip irrigation system and RWH. Although these studies have indicated the potential of the technologies in adapting to climate change, most of them did not critically examine the challenges of adopting these technologies. Therefore, this study has revealed that more studies need to be conducted, particularly in South Africa, regarding issues related to CSIT and the use of the different CSIT, as most of the past and recent studies have been conducted in either India or other sub-Saharan countries.

CHAPTER 3

FACTORS INFLUENCING THE ADOPTION OF CSIT FOR SUSTAINABLE CROP PRODUCTIVITY BY SHF IN ARID AREAS OF SOUTH AFRICA

3.1 Introduction

In most developing countries, underprivileged people depend directly or indirectly on smallholder crop production to sustain their livelihoods (Sinyolo, 2013). These resource-poor people are often referred to as smallholder farmers (SHF). They are mainly found in rural areas where agriculture is the main activity to alleviate poverty (Mango *et al*., 2018). Kamara *et al*. (2019) indicated an estimation of about 500 million SHF worldwide, upon which more than 2 billion people depend for their livelihoods. SHF has been at the forefront of stimulating rural economies in sub-Saharan Africa (Kamara *et al*., 2019). They support their households and local markets through products produced in less than three hectares of land (Mwangi & Kariuki, 2015; Abegunde *et al.,* 2020; Sinyolo, 2019). However, despite their contribution to rural economic development, most SHF, particularly in Africa, have been experiencing poor yields, food insecurity, and rural poverty due to extreme climatic events, climate variability, and change (Sinyolo, 2019; Owusu, 2016). Climate change refers to regional and global fluctuations in climatic patterns due to natural variability or human activity (Mazibuko, 2018; Kom *et al.,* 2020).

Cultivation practices are usually affected by climate change through the occurrence of extreme weather conditions such as heatwaves, droughts, flash floods, and changes in rainfall amounts and patterns, therefore causing shifts in the timing and length of growing seasons and differences in the prevalence and severity of pests, diseases, and weeds (Thornton *et al*., 2018).

Although all farming systems might experience the effects of climate change, SHF is usually the most vulnerable due to their high dependence on climate-sensitive rain-fed agriculture (Ubisi, 2016; Farid *et al.,* 2015). According to Maponya & Mpandeli (2012), most SHF has a low adaptive capacity and low resilience to deal with extreme climatic events, high climate variability, and change. South Africa falls among the 30th driest countries globally, and climate change has enhanced the situation further through changes in rainfall amounts and patterns (Mokgwathi, 2018; Chipfupa & Wale, 2019). The country receives a highly uneven annual rainfall distribution of approximately 500mm, compared to the global average of 860mm (Chipfupa & Wale, 2019). Although 70% of the grain crop production in the country occurs on dry land, only 35% receive enough rainfall required for successful dryland crop production. However, this is expected to vary across the different agro-ecological zones as areas represent unique combinations of homogenous agro climate, ecology, soil units, and agricultural activities, according to Fanadzo & Ncube (2018) and Stevens & Van Koppen (2015). With the climate being a prime factor that exerts major influence and control over vegetation, soil type, water resources, and ultimately human activities, semi-arid regions in Limpopo Province, which produce only a small fraction of grain production in the country, have become particularly vulnerable to climate variability and change by raising temperatures and erratic inter-seasonal rainfall patterns (Musetha, 2016).

Extreme weather conditions such as heatwaves and flash floods are estimated to become more frequent and intense in the Province (Marubini, 2018; Ranakoana, 2020). Although Ubisi (2016) and Ranakoana (2020) indicated that all five districts in the Limpopo Province were affected by climate change, the Vhembe district, in particular, has been identified as the most drought stricken. According to Maponya & Mpandeli (2012), the majority of SHF farmers in the Vhembe district have developed several coping and adaptation strategies to deal with both climate variability and change, and some of these strategies include adopting crop diversification, using hybrid seeds, adjusting fertilizer inputs, using plant crops that require less water, using multi-cropping systems, etc. To address climate variability and change impacts, some SHF in the area modified their farming practices by using traditional irrigation methods (TIM) based on their indigenous knowledge (Ubisi, 2016; Farid *et al.*, 2015). TIM include surface methods such as flooding, furrows, and basins (Nikolauo *et al*., 2020). In the past, using these methods was beneficial to farmers in reducing their vulnerability to drought spells, thus resulting in a more stable production and income generation (Salazar & Rand, 2016). Over the past years, existing literature has indicated that traditional methods have become ineffective for coping with climate change's medium and long-term impacts (Farid *et al*., 2015). Its use has been associated with the overexploitation of natural resources, increasing pressure on water reservoirs, creating pollution problems, consuming time and money, and low yields due to crop damage caused by over or under irrigation (Salazar & Rand, 2016; Mkuhlani *et al.,* 2020; Myeni & Moeletsi, 2020). Therefore, this has triggered much discussion about converting to more improved agricultural technologies such as climate-smart irrigation technologies (CSIT) (Nikolauo *et al*., 2020).

CSIT is defined as a good irrigation practice for a given agro-climatic and societal context that considers challenges and opportunities that may result directly or indirectly from different facets of climate change (Batchelor & Schnetzer, 2018). With proper planning and implementation, the use of CSIT such as RWH, drip, and sprinkler irrigation would assist in reducing the over-dependence on rainfall, usage of inefficient irrigation methods and address the challenges of poverty and food insecurity (Mwangi & Kariuki, 2015; Owusu, 2016; Kom *et al.*, 2020; Mkuhlani *et al.*, 2020; Patle *et al.*, 2020). However, despite the well-documented effectiveness and feasibility of CSIT to cope with climate change, particularly in resource-constrained rural communities, adoption remains low (Mwangi & Kariuki, 2015; Myeni & Moeletsi, 2020). Masela *et al*. (2018) indicated that in the Limpopo Province, only 16.6% had adopted CSIT. This may be because the impacts of climate change and several adoption characteristics have not been fully understood by these farmers, resulting in low adoption rates (Anuga *et al.*, 2019). Other factors for the low uptake of CSIT include the low levels of education and the age of the majority of the SHF.

Factors influencing SHF from adopting CSIT have not been investigated in detail in this country. However, studies done in Zimbabwe, Mozambique, Zambia, and Malawi show that any technology that will not help SHF increase their yields and improve their income and livelihoods will not be adopted easily. South Africa, prone to climate change, drought, and uneven rainfall distribution, affect smallholder production, which is more prevalent in the Limpopo Province. Against this background, the study was initiated to identify CSIT technologies and significantly assist SHF. This study aims to identify factors that influence adoption and the level of adopting CSIT.

3.2 Factors influencing the adoption of CSIT

Existing literature indicated that several factors are influencing the adoption of agricultural technologies. Mwangi & Kariuki (2015) demonstrated that farmers' decisions about whether and how to adopt agricultural technologies are conditioned by the dynamic interaction between the characteristics of the technology itself and the arrangement of conditions and circumstances. Below Figure 3.1 is a description of factors that play a role in influencing the adoption of CSIT by SHF. These factors have been categorized into demographic, farm characteristics, irrigation, and formal and informal training. This will enable an in-depth review of how each factor influences adoption.

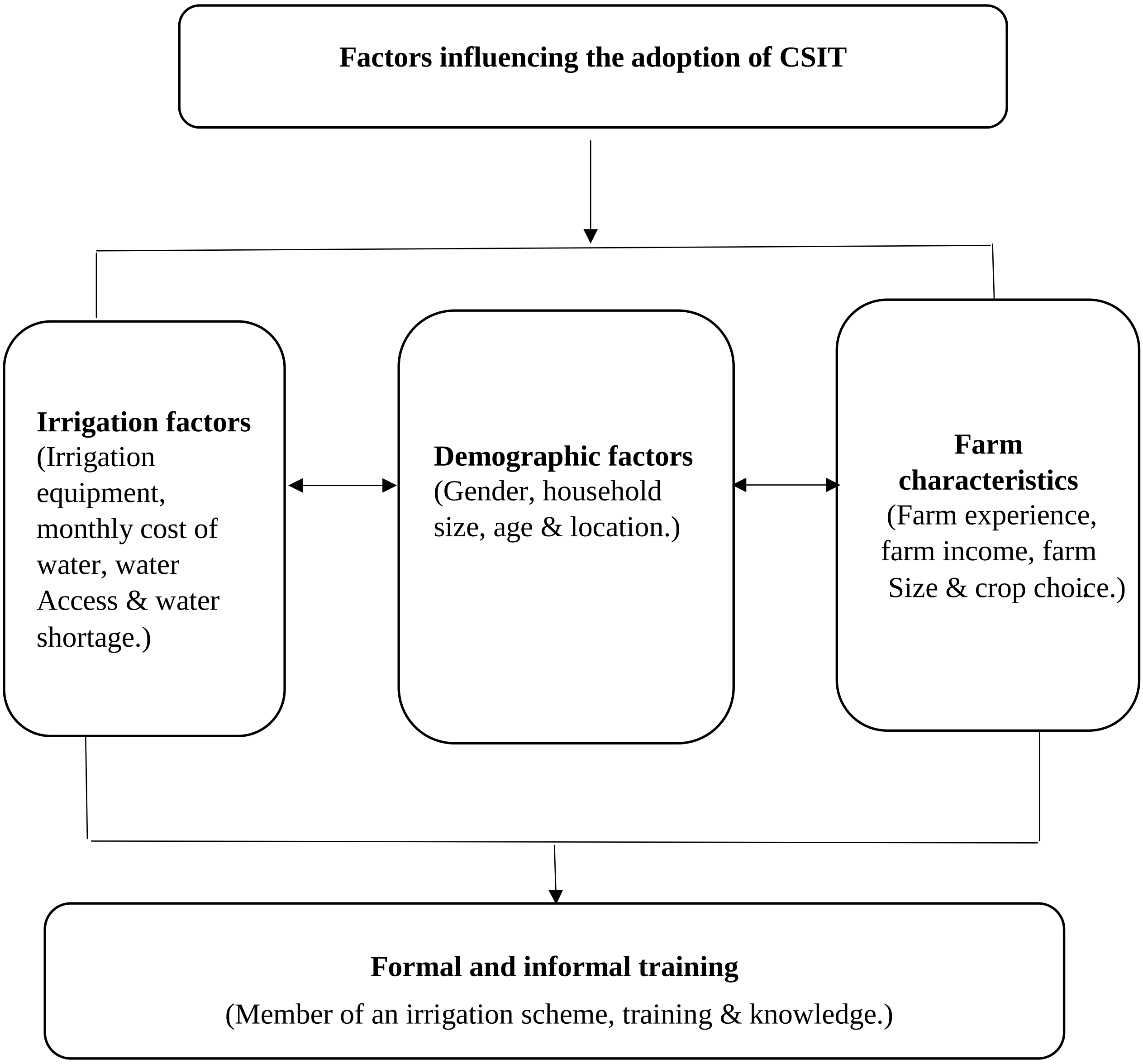

Figure 3-1: A conceptual framework for factors influencing the adoption of CSIT

3.2.1 Demographic factors

An understanding of gender composition in agriculture facilitates analyses of the roles, responsibilities, constraints, and opportunities for both males and females (Sani, 2017). Studies investigating the role of gender in agricultural technology adoption reported mixed evidence on the different roles of men and technology adoption (Mwangi & Kariuki, 2015). Shange (2015) found no significant association between gender and the adoption of technologies. As males and females play very different yet essential roles in agriculture, a clear distinction in labour divisions, roles, responsibilities, and access to productive resources is always present (Mokgwathi, 2018; Sipoko, 2014). On the other hand, gender may significantly influence a farmer's adoption of technologies. The household heads are usually the primary decision-makers with more access and control over vital production resources (Mwangi & Kariuki, 2015). This finding is consistent with Shange (2015), who reported that male-headed households have a higher chance of adopting in-field RWH technology than female-headed households.

The household size factor, which usually explains the number of people residing in one household, can be defined from two angles regarding technology adoption (Masela *et al.*, 2018; Saha *et al*., 2019). The first assumption is that households with large families are associated with cheap labour availability, enabling households to accomplish various agricultural tasks and remove labour constraints required to introduce new technologies (Sinyolo, 2013; Mwangi & Kariuki, 2015; Saha *et al*., 2019). Awinda (2018) also found that family labour availability allows the household head to share responsibilities and save time for other development activities. The second assumption is that large family sizes may pressure household consumption and other expenses rather than the purported labour it provides to farming (Saha *et al.*, 2019; Agolor, 2014). Therefore, other household expenses can limit irrigation technology adoption beyond the household budget (Adebayo *et al*., 2018).

Age is assumed to be among the many factors that play a role in influencing a farmer's decision to adopt agricultural technologies (Mwangi & Kariuki, 2015; Sani, 2017). Wekesa (2017) indicated that age could positively or negatively affect technology adoption. A positive relationship can result from the fact that older farmers are usually considered to have more experience, have accrued more assets, and developed wider social networks that enable them to have a higher likelihood of adopting technologies than younger farmers (Abegunde *et al*., 2020; Wekesa, 2017; Kurgat *et al.*, 2020). On the other hand, the negative relationship between age and adoption is explained by Van der Berg (2013), Lebeta (2017), Kurgat *et al*. (2020), and Aryal *et al.* (2018) as farmers grow old, they become reluctant in adopting new technologies by being more risk-averse and lack the physical ability for carrying out farm operations with short-planning horizons. By contrast, younger farmers are more adaptable and enthusiastic about new technologies (Patle *et al*., 2020; Van den Berg, 2013). For example, Shange's (2015) findings on the adoption of rainwater-harvesting techniques indicated that young farmers are always ready to take risks and adopt expensive but effective agricultural technologies to enhance their food security status.

Despite the number of efforts different institutions and stakeholders made to make farmers aware of improved agricultural technologies at a district level, some farmers are still unaware of these technologies (Nakawuka *et al*., 2017). The field survey results indicated that CSIT was already adopted by 73.91% of SHF in the Capricorn district. While in the Vhembe district, the percentage of adoption was much lower at 26.09%. The main reason is that in the Vhembe district, there is a considerable lack of knowledge regarding CSIT. Different climatic conditions in the Vhembe and Capricorn districts may influence the adoption of CSIT differently in each district. Nonvide (2017) added that the difference in technology adoption between the two regions is usually associated with the average profit gained from the adoption. Whereas Kom *et al.* (2020) indicated that the farmer's decision to adopt agricultural technologies is usually determined by the local agricultural cycle, including seasonal climatic variation and other socio-economic drivers. These findings are aligned with similar results highlighted by Maponya & Mpandeli (2012).

3.2.2 Farm characteristics

Experienced farmers generally have access to information due to efficient contact with extension services, providing relevant knowledge and skills (Abegunde *et al.*, 2020; Agholor, 2014). Experience also impacts the farmer's managerial ability to make decisions, enabling them to set realistic goals and achieve these (Sani, 2019). Therefore, the farming experience is expected to positively influence the farmers' decision to adopt CSIT. This suggests that the more farming experience one has, the more likely to adopt CSIT.

A key factor in adopting new technology is the farmer's income from adoption, including all the new technology costs (Mwangi & Kariuki, 2015). Farm income can positively or negatively influence technology adoption depending on its relative contribution to household or farm profitability (Shange, 2015). Abegunde *et al.* (2020); Ndamani & Watanade (2016) indicated that farm income could drive CSA adoption positively because increased income obtained from farming activities enables the farmer to acquire resources required for adoption. The majority of farmers in the Vhembe district indicated that any technologies that would assist them in increasing their income and yields would be adopted without any delays (Maponya & Mpandeli, 2012). On the other hand, some studies on technology adoption have indicated that the high cost of agricultural technologies can constrain adoption (Mwangi & Kariuki, 2015). Chuchird *et al*. (2017) revealed that farmers were faced with expenses in terms of equipment, maintenance, and fuel, which has led to a low farm income even after deducting expenses of using the water pump.

The farm size factor refers to the size of the cultivated land owned by the farmer in hectares. Farm size influences decision-making because it can limit farmers from adopting new technologies required for successful agricultural ventures (Abegunde *et al.,* 2020; Agholor, 2014). Many studies have investigated the effect of farm size on the adoption decision, and the results indicated that the impact depended on factors such as fixed adoption costs, risk preferences, human capital, credit constraints, labour requirements, tenure agreements, etc. (Shaw, 2014). Saha *et al.* (2019) pointed out that farm size can positively or negatively affect adoption, suggesting that the influence of farm size on technology adoption is inconclusive. The positive relationship is based on the assumption that farmers who cultivate larger farm sizes generate more income, enabling them to have a better capital base and enhancing their risk-bearing ability to adopt new technologies than their counterparts (Shange, 2015; Saha, 2019). On the other hand, the negative relationship can result from the fact that cultivation on larger land areas requires significant financial investments in labour and inputs, which can be too costly for resource-poor farmers (Myeni & Moeletsi, 2020).

The Limpopo Province is known for producing a wide variety of agricultural produce. Maponya & Mpandeli (2012) indicated that the province usually emphasizes growing maize and vegetables. Maponya and Mpandeli (2012) further highlighted that crop diversification forms part of the risk aversion strategy to deal with extreme climatic events, high climate variability, and change. However, most farmers in the Vhembe district practice mono-cropping, allowing them to have consistent crops throughout their entire farm. This will negatively impact the long run as the soil will become less productive because organic matter is reduced, and erosion will be enhanced. Adoption enhances the production of crops, particularly those that cannot be cultivated under dryland. Higher yields mean that most households will be food secure as SHF usually produces for household consumption, and the surrounding communities can benefit from lower food prices (Ziba, 2015). Furthermore, farmers may be unenthusiastic about practising supplemental irrigation on maize because they do not see the production value and instead irrigate vegetables.

3.2.3 Formal and informal training

Being a member of an irrigation scheme has a positive and significant influence on technology adoption because it creates a convenient platform where farmers can learn about the benefits and usage of new technology (Mwangi & Kariuki, 2015; Shaw, 2014). This result concurs with the findings of Wekesa (2017) and Anuga *et al*. (2019), who indicated that group interactions whereby members can exchange ideas, handle farm demonstrations, and get connections for dissemination of significant research findings would create a strong bond between farmers thus enabling the easy transmission of information.

Training plays an essential role in technology adoption as it provides farmers with the required technical skills (Dlangalala & Mudhara, 2020). To adopt a particular technology, much time should be invested in farmer awareness, learning, and experimentation (Nakawuka *et al*., 2017). Key players such as the government, NGOs, and private sectors provide training to farmers through various agricultural development programs (Njoko & Mudhara, 2017). SHF in rural areas usually rely on extension officers for skills training; therefore, those with regular contact have a higher chance of adopting agricultural technologies (Musetha, 2016). Jha *et al*. (2017), who studied water productivity and economics of vegetable production under drip and furrow irrigation, reported that when farmers are part of the irrigation installation process, it will broaden their knowledge of the system. They might learn to tackle minor repairs to the system. Whereas Agholor (2014) indicated that agricultural development initiatives such as CSIT should start with training the targeted farmers before any other support services are provided.

Knowledge is the main factor in determining SHF technologies (Myeni & Moeletsi, 2020), as it is the first step to adopting innovative technology, particularly one that is not yet widely known (Shaw, 2014). Farmers will only adopt the technology if they know its existence and effective use (Mwangi & Kariuki, 2015; Wekesa, 2017). Awareness can be created through various sources of information such as extension officers, NGOs, farmer's associations, radio and television etc. (Musetha, 2016; Shaw, 2014). Musetha (2016) and Wekesa (2017) indicated that the availability of extension services plays an essential role in creating awareness of the adoption of new technologies as farmers are exposed to new information and equipped with technical skills through field demonstrations. Therefore, the more farmers contact extension officers, and the more knowledge is acquired, as technology adoption requires new skills, including observation, monitoring, and risk assessment (Wekesa, 2017). This is consistent with Adebayo et al. (2018) findings that more educated farmers have better knowledge regarding the importance of adopting new technologies. Although most farmers may be aware of agricultural technologies, only a small number adopt the practices (Ouédraogo *et al*., 2019).

3.2.4 Irrigation factors

The introduction of irrigation equipment such as pumps has resulted in a reliable water supply (Sinyolo, 2013; Nakawuka *et al*., 2017). Farmers use different energy sources such as diesel, petrol, and electricity (Ouédraogo *et al*., 2019). Therefore, technology adoption is usually determined by how water is channelled to the farmer's field (Sinyolo, 2013). On the other hand, the lack of affordability of this water access equipment can limit technology adoption, thus negatively affecting food security (Namara *et al*., 2013). However, farmers have found an alternative by buying this equipment as a group and using them based on ground rules (Getacher *et al*., 2013).

The monthly cost of water negatively influences the adoption of CSIT, as the marginal costs of surface water are usually lower than the costs for groundwater (Osewe *et al.*, 2020). Sinyolo (2013) found that farmers who use gravity do not pay for water; therefore, they are often limited in demanding water when it does not reach their plots. However, the only cost of water would be bringing water to one’s plot, depending on the distance (Nakawuka *et al.*, 2017). These costs can discourage struggling farmers who usually generate a low farm income (Frisvold & Bai, 2016). Therefore, this can have a negative influence on the adoption of CSIT.

On the other hand, Frisvold & Bai (2016) indicated that monthly water costs positively and significantly affect CSIT technology, such as sprinkler adoption. Nonvide (2017) agreed with this finding by demonstrating that farmers are usually sensitive to the increase in water prices therefore, it would encourage them to adopt the most efficient technology and discourage the adoption of the least efficient options. According to Njoko & Mudhara (2017), irrigation water fees should be set at a price level that most farmers can afford. Water access, which has been captured as the number of days the farmers have access to water in their plots, may positively or negatively influence a farmer’s decision to adopt CSIT.

In most rural areas, the primary water source includes rainfall, dams/rivers, communal taps, wells, and boreholes however, because of the different rainfall amounts received, some water sources are seasonal, thus making it challenging for rural farmers to produce annually (Mazibuko, 2018; Sipoko, 2014). In the Tshiombo irrigation scheme in the Limpopo Province, SHF highlighted that water access is a serious challenge, especially for farmers that have plots far away from the canal system, and this group of farmers claim that due to the limited amount of water available, they are getting low crop yields compared to SHF who have plots close to the canal system (Maponya & Mpandeli, 2012). Limited water access has also created tension amongst SHF in the Tshiombo irrigation scheme. Water shortage is still described as one of the many constraints to improving rural people's lives (Shange, 2015). It is usually caused by irregular rainfall and high evaporative demand limiting rain-fed agriculture production in South Africa, making it almost impossible to perform agricultural activities as farmers' SHF are located in marginal and unsuitable crop production areas (Shange, 2015; Dlangalala & Mudhara, 2020; Zhou & Abdullah, 2017). These marginal areas may range from semi-arid to arid and receive deficient rainfall (Shange, 2015). Therefore, the adoption of CSIT may positively affect production, as a change in the water management paradigm is required so that the demand can be met (Kanjere *et al*., 2014).

3.3 Materials and methods

3.3.1 Study Area, Sampling and Data Collection

The Limpopo Province is located in the far Limpopo Province of South Africa, and it links the country with the rest of Southern Africa. This province comprises five districts, namely: Sekhukhune, Mopani, Capricorn, Waterberg, and Vhembe (Figure 3.2), which are made up of three distinct climatic regions: the low-veld (arid and semi-arid) regions, the middle veld, highveld, and semi-arid regions (Ubisi, 2016). The experience of varied climates ranging from arid to semi-arid enables the province to produce various agricultural produce, as it accounts for nearly 60% of fruit, vegetables, cereal crops (maize and wheat), and cotton] produced in South Africa (Stevens & Van Koppen, 2015; Lekalakala, 2017). This is among the many reasons why the province has been referred to as the breadbasket and agricultural engine of

South Africa (Lekalakala, 2017). Despite the tremendous agricultural potential, the province is vulnerable to climate variability and change as decreasing rainfall amounts, altered rainfall distribution, and rising air temperatures, which are expected to advance, have already been witnessed. The study was carried out in the Capricorn and Vhembe districts since most farmers in these two districts still produce crops under TIM. In the Vhembe district, climate conditions are subtropical, with mild, moist winters and wet, warm summers that frequently experience dry spells, often growing into a severe drought (Maponya & Mpandeli, 2012). The rainfall pattern ranges from 246 mm to 681 mm per annum, with over 80 percent of the rainfall occurring between October and December (Musetha, 2016). The district also experiences extremes in temperatures that can reach more than 35 °C during summer. In the Capricorn district, the annual rainfall varies from less than 400 mm in the north to 500 or more south of Polokwane. With summer temperatures ranging from mild to warm (Tmax on January 27–28 °C) on the Polokwane plateau and warm to hot (Tmax on January 29–32 °C) over the bulk of the area (Selejio & Lasway, 2019).

Therefore, CSIT adoption is critical to building climate-resilient farming communities, improving crop yields and food security, and alleviating poverty as the potential effects of climate change continue to threaten agricultural production and sustainability. Data were collected during September 2020 using a structured questionnaire. The questionnaire comprised open-ended questions that enabled individuals to express their opinion. However, the majority of the questions were closed-ended. This design simplified the process of capturing information by extracting as much information as possible from the respondent without too much time. The survey questionnaire covered a wide range of information, including demographics (gender, age, education level, household size, etc.), farm characteristics, irrigation sources, and institutional characteristics. Trained enumerators who knew the rural farming system well and spoke the local languages, i.e., Sepedi (Capricorn district) and TshiVenda (Vhembe district), administered the questionnaire to guard against the problem misinterpretations or misunderstandings of words or questions. A convenience sampling technique was used to select 100 SHF from the purposely selected two districts within the province. The main characteristics of the targeted SHF farmers were that they should use any irrigation system, be vegetable growers, and be based in one of the two districts. The list of SHF was obtained from the respective local offices of the Limpopo Department of Agriculture and Rural Development (LDARD). A survey method was used for data collection through face-to-face interviews. The study was also conducted ethically by firstly explaining the purpose of the survey to all participants, secondly by letting participants sign the consent form as an agreement to participate in the study, and thirdly by explaining how data would be collected, analyzed, and interpreted in such a way that the procedure does not harm the participants and that their privacy was protected. In relation to the Covid19 pandemic, personal protective equipment (PPEs) were provided to all enumerators and farmers participating in the study. Social distancing at 1.5 m was observed at all times.

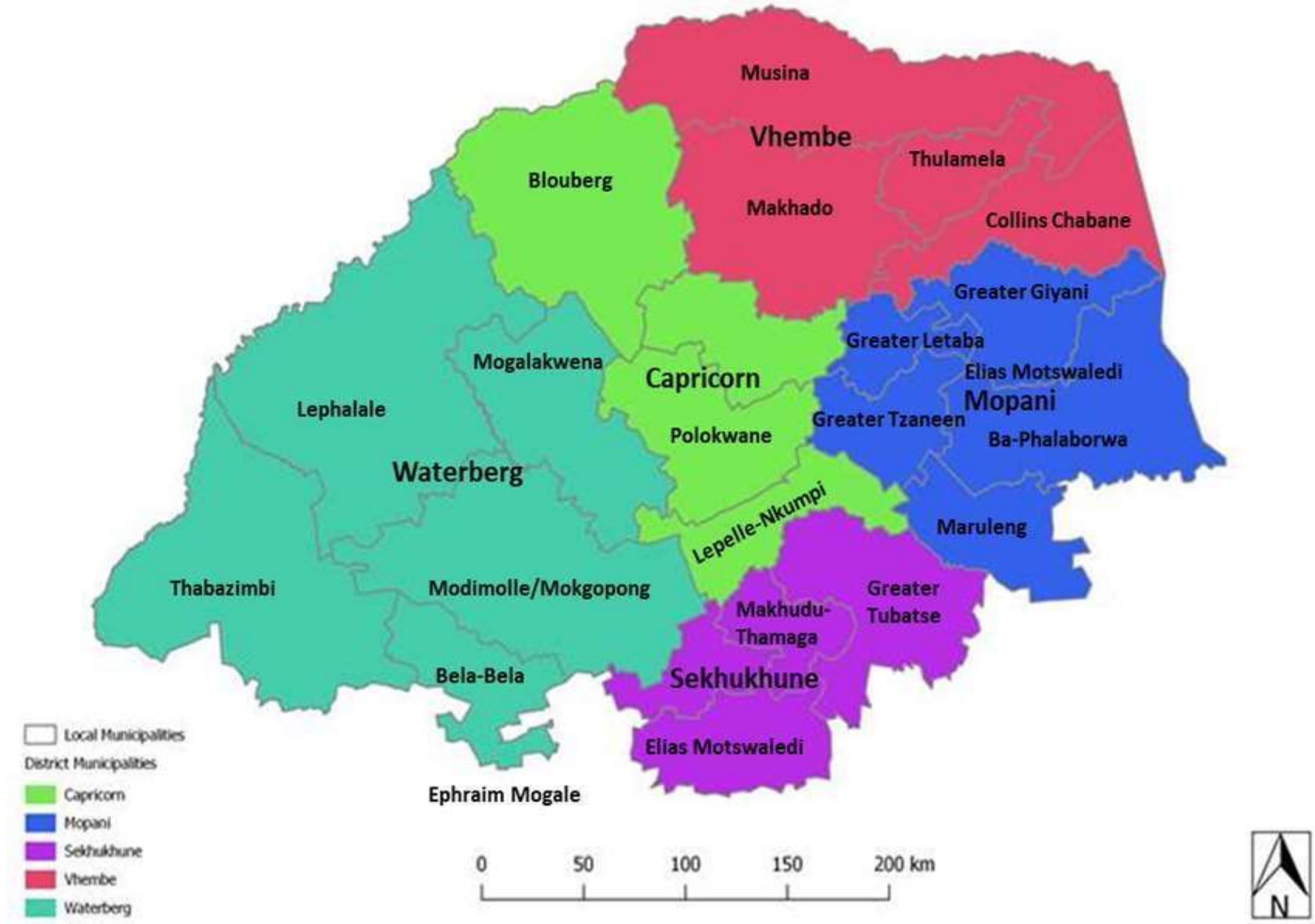

Figure 3-2: Map of the Limpopo Province showing the districts within the province.

3.3.2. Analytical Model used in the study

Descriptive statistics summarize the data using Software for Statistics and Data Science (STATA 15). The Probit regression model was used to determine factors influencing CSIT adoption by SHF. Whereas the OLS regression model was applied to evaluate the level of adopting CSIT. These different analytical techniques are explained in detail in the following sub-sections.

3.3.3 Probit regression model

The Probit regression model was selected because the dependent variable is binary and takes a value of 0 or 1, meaning that it takes 1 if the SHF adopted CSIT and 0 otherwise. Limitations associated with a linear probability, such as non-normality of the error and the given probabilities that can exceed 1 or be lower than 0, can be solved by the Probit model grounded in normal cumulative distribution functions (CDF) (Selejio & Lasway, 2019). The model assumes that SHF will make adoption decisions based on the objective of maximizing utility (Shaw, 2014). The underlying utility function usually depends on various factors examined and an error term with a mean of zero (Ziba, 2015). The conceptual analysis of the model used in this paper is similar to the model adopted by Esabu & Ngwenya (2019); Shange (2015) to estimate the adoption of improved agricultural technologies by farming households. This study refers to the following equations: (Shaw, 2014; Esabu & Ngwenya, 2019).

$$U_{i1} = \beta_1 X_i + \varepsilon_{i1} \text{ for adoption} \quad (1)$$

$$U_{i0} = \beta_0 X_i + \varepsilon_{i0} \text{ for non-adoption} \quad (2)$$

Based on the fact that utility is random, the ith SHF will select the alternative "adoption" only if Ui1 > Ui0. Therefore, for the smallholder farmer i, the probability of adoption is indicated by:

$$P(1) = P(Ui1 > Ui0) \quad (3)$$

$$P(1) = P(\beta 1Xi + \varepsilon i1 > \beta 0Xi + \varepsilon i0) \quad (4)$$

$$P(1) = P(\varepsilon i1 - \varepsilon i0 < \beta 1Xi - \beta 0Xi) \quad (5)$$

$$P(1) = P(\varepsilon i < \beta Xi) \quad (6)$$

$$P(1) = \Phi(\beta Xi) \quad (7)$$

Where, Ui1 = The utility a farmer obtains from the technology; Ui0 = No utility obtained by a farmer from the technology; **P (**1) = Probability of adopting CSIT technology; β0... β1 = Estimated parameters; Xi = Independent variables; Φ = is the cumulative distribution function of the standard normal distribution. εi = Disturbance term in the situations of a normal distribution function, the model used to estimate the probability of adopting CSIT among surveyed farmers can be presented as:

$$P\,(Yi = 1|\,x) = \Phi\,(x\beta) = \int_{-\infty}^{x\beta} \frac{1}{\sqrt{2\pi}} \exp\,(-\,z^2/\,2)\,dz \qquad (8)$$

Where P stands for the probability that the i_{th} SHF adopted CSIT and 0 otherwise.

The simple latent form of the Probit model is below where:

$$Y^* = \beta 0 + x\beta + \varepsilon \qquad (9)$$

In the equation indicated above, ε| x is an error term that is normally distributed. Y* is an underlying index that reflects the difference between the utility derived from technology adoption.

3.3.4 OLS regression model

Ordinary Least Squares (OLS) has been identified as one of the most popular methods used for data analysis because it can be applied to single, multiple, or appropriately coded categorical explanatory variables however, it mainly assumes linearity, which was satisfied by the data used for this study (Mwadzingeni *et al.*, 2020; Olvera & Zumbo, 2019). However, the model would result in biased and inconsistent estimates (Olvera & Zumbo, 2019). Therefore, to ensure the best estimates from OLS, several assumptions must be satisfied, including the one of constant error variance (i.e., homoskedasticity) (Olvera & Zumbo, 2019). According to Njoko & Mudhara (2017), the OLS regression model can be specified as follows:

$$Yi = \beta 0 + \beta iXi + \beta 2\ X2 + \beta iXi + ei \qquad (11)$$

Where Yi is the dependent variable, which is the water access per week for the ith SHF; Xi is a vector of independent variables; β0 and βi are the vectors of parameters to be estimated, and ei is the error term.

3.4. Results

3.4.1. Characteristics of SHF

The descriptive results from continuous variables used in the study indicated minor to almost no differences between adopters and non-adopters of CSIT for most parameters (Table 3.1). An adopter farmer is 48 years old, while a non-adopter farmer is 49 years old. The average household size for both groups consists of five people. The results indicated that the average land size cultivated by adopters and non-adopters of CSIT in the study area is 3.7 ha and 3.3 ha, respectively. In addition to the total farm size used by adopters and non-adopters, a large amount of land is still significantly utilized for dryland production. There is a significant difference in farming experience as adopters have an average experience of 9 years compared to the 11 years experience of the non-adopters.

The results also indicated an insignificant difference in farm income between adopters and non-adopters. As the average farm income of non-adopters was R30585.00 per season, the farm income of the non-adopters was slightly higher at an average amount of R31450.00 per season. The possible explanation for the low farm income of adopters is that SHF was not exposed to the full potential of CSIT, such as mulching which is meant to conserve moisture without any extra operational and maintenance costs. On average, four workers per season are employed to carry out activities by adopters. Adopting CSIT resulted in SHF having access to water an average of 5 days per week while paying a reasonable R2555.00 per month. As irrigation often takes place on a schedule, there are low water costs. In comparison to non-adopters who have access to water an average of 4 days per week, the cost is R3658.00 per month. The high water costs amongst non-adopters are often due to TIM, such as flood irrigation, which uses a large amount of water.

Table 3-1: Continuous variables description

Variable	**Adopters (N=46)**		**Non- adopters (N=54)**		**Total (N=100)**		**T tests (χ2 tests)**
	Mean	**Std.Err**	**Mean**	**Std.Err**	**Mean**	**Std.Err**	
Household number (number)	5.34	0.37	5.33	0.25	5.34	0.25	ns
Age (years)	48.30	2.13	49.14	1.86	48.76	1.86	ns
Farming experience (years)	8.58	1.20	10.53	1.05	9.64	1.05	**
Number of labourers number (number)	4	0.59	2.97	0.30	3.40	0.30	ns
Farm income per season (Rand)	30585.8	8952.5	31450.74	7527.4	31052.9	7527.4	**
Farm size used (ha)	3.74	0.61	3.33	0.81	3.49	0.81	ns
Water cost (R/month)	2555	681.8	3658.4	870.63	2984.1	870.6	ns
Water access (per/ week)	5.41	0.30	4.62	0.39	4.99	0.39	ns

Note: ***, **, and * mean significant at 1%, 5 %, and 10%levels, and n.s means not significant.

Table 3.2 presents the descriptive results of the categorical variables used in the study. The results show that males (50%) and females (50%) play an equal role in adopting CSIT, whereas the majority (59.26%) of non-adopters were females. The Capricorn district had the most adopters (73.91%), while most SHF (70.37%) in the Vhembe district decided not to adopt CSIT. Shange (2015), who studied the adoption of rainwater-harvesting technology, pointed out that a farmers' decision to adopt agricultural technology in a particular area depends on how SHF perceives it. Most SHF-producing staple food and tubers did not adopt CSIT. The possible reason for the low adoption of CSIT may be that most SHF still regards their staple food, such as maize, to be a dryland crop, or it may be that farmers lack awareness about how vegetables such as tubers thrive under irrigation, particularly CSIT (Myeni & Moeletsi, 2020). Very few (6.52%) of the adopters were members of the irrigation scheme. This may result from the fact that group members are perceived differently amongst SHF; therefore, individual comparative advantage plays a vital role in deciding whether to join a group (Maponya, 2021).

Farmers also cannot contribute the monthly fee required to maintain the irrigation scheme as most of them live below the poverty line. Most SHF had access to training; however, CSIT adopters knew about CSIT, while the non-adopters did not know (80.43%). Apart from the indigenous knowledge that farmers have had for many decades, frequent contact with extension officers and participation in training workshops has contributed to the high percentage of knowledge access among adopters (Shange, 2015). The results also suggested that most adopters (86.96%) used an electric pump to access water from different sources, while non-adopters used both gravity (44.23%) and electric pumps (40.38%). Furthermore, (73.91%) of adopters experience water shortages, while (52.83%) of non-adopters use gravity and electric pumps. As a result, farmers may be discouraged from adopting CSIT due to a lack of relevant resources.

Table 3-2: Categorical variables description

Variable	Category	Adopters (N=46)	Non-adopters (N=54)	Total (N=100)	T tests ($\chi 2$ tests)
Gender	Male	50.00	40.74	45.00	
	Female	50.00	59.26	55.00	ns
District	Capricorn	73.91	29.63	50.00	
	Vhembe	26.09	70.37	50.00	***
Staple food production	Yes No	13.04	55.56	36.00	
		86.96	44.44	64.00	***
Tuber production	Yes No	4.35	9.26	7.00	
		95.65	90.74	93.00	**
	Yes	6.52	37.04	23.00	
	No	93.48	62.96	77.00	
Member of the irrigation scheme					**
Training on CSIT	Yes No	80.43 19.57	70.37 29.63	75.00 25.00	
					ns
	Yes	97.83	16.67	54.00	
Knowledge of CSIT	No	2.17	83.33	46.00	*
	Diesel pump	8.70	11.54	10.20	
	Electricity pump	86.96	40.38	62.24	
	Generator	0.00 4.35	1.94	1.02	
	Gravity	0.00	44.23	25.51	**
Irrigation equipment	Solar		1.92	1.02	
	Yes	73.91	47.17	60.61	
	No	23.91	52.83	39.39	**
Water shortage					

Note: ***, **, and * mean significant at 1%, 5 %, and 10%levels, and n.s means not significant

3.4.2. Relationship between Socio-Economic Factors and Adoption of CSIT

Table 3.3 presents the maximum likelihood estimates of the Probit model adopting CSIT. The value of the Pseudo R2 (48%), the log-likelihood (−15.51), and the LR Chi2 (significant at the 5% level) indicate that the model's specifications provide a good fit for the data. The model had no multicollinearity problems, as it had a low average variance inflation factor (VIF) of 1.71. The regression results revealed that gender was significant at the 1% and 10% levels and positively influenced both a farmer's decision to adopt CSIT and the level of CSIT adoption, respectively. This implies that the probability of males adopting CSIT increases by 68% compared to their female counterparts.

In comparison, the level of adoption was more likely to increase by 2.35%. The household size was positive and significant at the 1% and 10% levels in influencing both farmers' decision to adopt CSIT and the level of adopting CSIT, respectively. This implies that an increase in household size by one member increases the probability of SHF adopting CSIT by 21%. Therefore, larger households are more likely to increase adoption by 39%. Age was significant at 10% and related positively to the level of CSIT adoption. This implies that a one-year increase in the farmer's age is more likely to increase CSIT adoption by 6%. The estimated coefficient of the district was positive and significant at the 5% level in influencing a farmer's decision to adopt CSIT. This implies that farmers in the Capricorn district have a 52% likelihood of adopting CSIT than farmers in the Vhembe district. The farming experience variable was negative and significant at the 5% level in explaining the level of CSIT adoption. The negative effect implies that a decrease in farming experience is more likely to cause a decline in CSIT adoption by 21%. The estimated coefficient of farm size was positive and significant at the 5% level in influencing farmers' decision to adopt CSIT. The estimated positive coefficient indicates that an increase in farm size by one hectare increases the probability of CSIT adoption by 4%. The production of staple food was observed to have a positive and significant influence on the farmers' decision to adopt CSIT at the 5% level; however, this factor did not influence adoption. This means that farmers who cultivate crops such as maize have a 28% probability of adopting CSIT. Whereas the production of tubers revealed a negative and significant influence on the SHF decision to adopt CSIT at the 1% level and no effect on the level of adoption. The negative coefficient suggests that the probability of adoption could decrease by 25% for SHF that produce tubers. It may be that SHF is shifting to crops with good market prices or that the type of production system used in the district is unsuitable for these particular crops. Knowledge of CSIT had a positive and significant effect on the adoption of CSIT at the 1% level. This suggests that SHF who have been equipped with the necessary knowledge regarding CSIT have a 31% higher chance of adopting CSIT.

Table 3-3: Factors influencing the adoption of CSIT: The Probit and OLS model results

Variables		Adoption Coefficient	Std. Err	Level of adoption Coefficient	Std. Err	Marginal Effects dy/dx	Std.Err
Gender	1 if male, 0 otherwise	3.073 ***	.955	2.350*	.793	.687 ***	.143
Household size	Number	.839 ***	.252	.390**	.169	.217 ***	.061
Age	Years	-.024	.040	.064*	.035	-.006	.010
District	1 if Capricorn, 0 otherwise	1.829**	.937	-	-	.529**	.260
Farming experience	Years	-.126	.080	-.217**	.063	-.032	.021
Number of labourers	Number	-.165	.187	-.152	.152	-.042	.044
Farm income per season	(Rand)	-6.240	4.206	-.2040	4.680	-1.620	.000
Farm size used	ha	.190**	.081	.008	.075	.049**	.022
Staple food production	1 if yes, 0 otherwise	1.102**		.365	.414	.285**	.137
Tuber production	1 if yes, 0 otherwise	-.985 ***		-.280	.354	-.255 **	
Member of irrigation scheme	1 if yes, 0 otherwise		.553				
Training on CSIT	1 if yes, 0 otherwise	-.710	.380	-.217	1.305	-.226	.097
Knowledge on CSIT	1 if yes, 0 otherwise	.333	1.320	.810	.755	.092	.471
			.628			.313 ***	.185
	1 if yes, 0 otherwise	1.212 ***	.496	-.071	.481		.111
Irrigation equipment	1 if electric pump, 0 otherwise	1.740*	.939	1.560*	.907	.577**	.290
Monthly cost of water	Rand	-.000*	.000	.000***	.000	-.000*	.000
Water access per week	Number	-.846 ***		-	-	-.219***	.066
Water shortage	1 if yes, 0 otherwise	-.488	.213	-1.659**	.684	-.123	.146
_cons		.032	.563 2.169	1.220	2.338		

Number of obs	45
Wald chi2(17)	28.61
Llog likelihood	15.511971
Prob > chi2	0.0383
VIF	1.71

Note: ***, **, and * mean significant at 1%, 5 %, and 10% levels, and n.s means not significant (N=100).

Empirical results indicated that farmers who have access to irrigation equipment such as pumps reflected a positive and significant relationship at the 10% level in influencing both farmers' decision to adopt and level of adopting CSIT, respectively. This means that SHF with access to irrigation equipment have a 57% probability of adopting CSIT, and the level of adoption is more likely to increase by 1.56%. Sinyolo (2013) indicated that farmers with water access equipment such as pumps usually have a reliable water supply. The monthly cost of water showed a negative and significant influence on the adoption of CSIT at the 10% level. This implies that SHF who cannot afford the required monthly cost of water are less likely to adopt CSIT.

In most cases, SHF in the rural areas are unemployed and depend on agriculture for income. Therefore, finance will always be a challenge when farmers only produce for household consumption and have limited market access. While the level of adoption was positive and significant at a strong 1% level, implying that if SHF were able to afford the water cost per month, it would have increased the level of CSIT adoption. The relationship between water access per week and the adoption of CSIT is negative and significant at the 1% level. The negative coefficient indicates that the probability of SHF adopting CSIT decreases by 21% when they continue to have less access to water. The ones that are often affected are those located at a distance from reliable water sources such as dams and rivers. Water shortage had a negative and significant influence on CSIT adoption at 5%. Increasing water shortages could decrease the likelihood of increasing CSIT adoption amongst SHF by 1.65%. This result is consistent with the findings of Zhou & Abdullah (2017), who indicated that water shortages make it impossible to perform agricultural activities.

3.5. Discussion

This paper aims to assess the factors influencing the adoption of CSIT for sustainable crop productivity by SHF in the Limpopo Province from two selected local districts, namely the Capricorn and Vhembe districts. Results on the category of the respondents based on their level of use of CSIT reveal a similar pattern in both districts. The majority of the respondents fell into the non-adopter category, while the least proportion fell into the adopter category. However, there is a higher proportion of respondents in the non-adopter category in the Vhembe district when compared to the Capricorn district. These findings suggest that the sampled SHF in the Vhembe district are better adopters of CSIT than those in the Capricorn district. While our results showed that 46% of the SHF adopted CSIT, Masela (2018) reported only 16.6% for the adoption rate of CSIT. The limitation is that the study only relied on data collected from the SHF under the irrigation schemes.

At the same time, 46% reported including the adoption of CSIT for many characteristics of individual SHF and those under the irrigation schemes. The results indicated a similar pattern in age distribution in the sampled SHF, revealing that more aged people were involved in farming than youths in both districts. The low level of involvement of youths in agriculture could be because they find agriculture unattractive and prefer to search for jobs in other sectors. However, the dominance of older farmers in the farming system could be an advantage in terms of wealth experience and social capital. This result is consistent with Mokgwathi (2018) findings and Abegunde *et al*. (2020). The expectation was that CSIT adoption would be higher amongst younger farmers because they are more innovative regarding adopting agricultural technology and not reluctant to take risks (Mokgwathi, 2018; Lebeta, 2017; Aryal *et al*., 2018). Results on the gender indicated that males and females were represented equally in the Capricorn district. While in the Vhembe district, a large proportion of the sampled farmers were males. However, it has been found that males are more likely to increase adoption. This is often a result of dominant cultural biases where males still have exclusive rights to make farm decisions regarding short-term and long-term adjustments (Shange, 2015; Sinyolo *et al*., 2014). In contrast, women are often faced with social, cultural, and financial barriers that limit them from accessing the required resources for CSIT adoption (Shange, 2015; Sinyolo & Mudhara, 2018). This factor had a positive and significant influence on both the adoption and level of adopting of CSIT.

The average household size of the sampled SHF indicates that the activities required for CSIT adoption will be handled despite an external labour force. The possible explanation could be that an increase in household size is often associated with the availability of cheap labour that would enable a household to accomplish various agricultural tasks, particularly in labour-intensive technologies, thus reducing the labour constraints (Abegunde *et al*., 2020; Shane, 2015; Saha *et al.,* 2019; Wekesa, 2017). The result concurs with the findings of Marie *et al*. (2020). The particular district where the smallholder farmer is based also plays a role in adopting CSIT. For instance, the Capricorn district has a higher adoption rate than Vhembe. This may be because farmers in the Capricorn district have regular contact with extension officers who equip them with the appropriate skills and knowledge regarding CSIT. The results indicated a high farming experience for the sampled farmers in the two districts, which is in line with the descriptive evidence of the dominance of older farmers in the study areas. However, the non-adopters had more farming experience than the adopters, thus resulting in the farming experience having a negative and significant influence on the level of CSIT adoption. This result suggests that when SHF have less experience, it often restricts them from exploring the many benefits that come with the adoption of CSIT. This result also suggests that involving experienced farmers in promoting CSIT among SHF can substantially impact the uptake of various CSIT practices and decrease the implementation of CSIT related programs and projects among SHF. The size of the farmland had a positive and significant influence on the farmers' decision to adopt CSIT, thereby implying that land fragmentation could be a constraint to CSIT adoption. Land is a crucial resource in agricultural production, and farmers will be able to accommodate innovations or practices necessary for a successful agricultural venture with access to land and other needed resources. This result concurs with the findings of Abegunde *et al*. (2020), Lebeta (2017), Hailu (2014), Donkoh *et al*. (2019). Furthermore, cultivation on large farms would allow the SHF to experiment with the different CSIT technologies, thus enhancing their risk-bearing ability (Sani, 2017; Sipoko, 2014; Adebayo *et al.*, 2018). However, based on the results, there is a difference in the degree of the adoption practices. In the Vhembe district, adopters are less likely to adopt CSIT. The findings on knowledge revealed that it had a positive and significant impact on the level of CSIT adoption. However, it is most likely those equipped with the necessary skills and knowledge have a higher chance of adoption. In most cases, SHF obtains knowledge from reliable agricultural information sources such as extension officers, media, irrigation committees, and fellow farmers (Njoko & Mudhara, 2017). The actionable guidelines for implementing CSA published by the Department of Environment, Forestry, and Fisheries have paved the way for the rollout of CSA (CSA) in South Africa. Sani (2017) indicated that education is an important factor in determining SHF's ability to understand policies or programs affecting the adoption of CSIT. This is consistent with Adebayo et al. (2018), who pointed out that in most cases, the expectation would be that farmers who are more educated have better knowledge of the importance of adopting new technologies.

3.6. Summary

This study used the Probit and OLS models to determine the factors influencing the adoption and the level of adopting CSIT by SHF to improve sustainable productivity. Several factors, categorized as demographics, farm characteristics, economic factors, and formal and informational training, influence a farmer's decision to adopt CSIT. Based on the study's evidence, few SHF adopted CSIT, and males and females played an equal role in the adoption process, thus removing gender inequality issues. In addition, it was mostly older farmers with experience who adopted CSIT due to the indigenous knowledge obtained over the years and the exposure to secondary factors (such as funding and established enterprises). The study would make the following contributions to the theoretical and empirical literature and understand the adoption of CSIT by SHF. This particular study focuses only on the Limpopo Province in South Africa, and it contains valuable information that SHF can use in other provinces to adopt CSIT. Therefore, the factors that have been included in this study can be explored in terms of formulating strategies and implementing processes that would assist in developing programs aimed at improving the livelihood of SHF through the adoption of climate-smart irrigation. It has been found that literature on factors that influence the adoption of climate-smart irrigation in South Africa is limited. Therefore, the results of this study will provide an empirical contribution to the existing literature that identifies factors that play an essential role in adopting climate-smart technologies by SHF.

The study recommends that stakeholders in the agricultural sector, such as extension officers, should continue educating SHF about CSIT, mainly because they are the ones who are usually affected negatively by climate change. This can be done by organizing workshops and farmers' days. In order to fast track the adoption of the CSIT amongst SHF, there is a need to provide capacity building, technology transfer demonstrations, and strengthen knowledge dissemination as part of the science-policy interface. The farmers will be able to interact with companies and see the different equipment required to adopt CSIT. This would enable the farmers to acquire accurate information to adopt CSIT.

CHAPTER 4

CHALLENGES FACED BY SHF IN ADOPTING CLIMATE-SMART TECHNOLOGIES TO ENSURE SUSTAINABLE AGRICULTURAL PRODUCTIVITY IN THE LIMPOPO PROVINCE

4.1 Introduction

In South Africa, the agricultural sector is referred to as the foundation of developing economies because not only does it contribute approximately 3% of the countries' Gross Domestic Product (GDP) and 30% of the labour force; the sector is also a source of food and household income required to meet the basic survival needs of vulnerable communities (Streck *et al.*, 2012; Mgendi *et al.,* 2021; Mwadzingeni *et al.,* 2020). Land productivity remains distressfully low despite the sector's acclaimed contribution to economic growth. The country's specific ecological and environmental conditions have made it vulnerable to climate variability and change (Mukasa, 2016; Ceci *et al.*, 2021). Exposure to several global climatic drivers will likely increase the incidence and severity of extreme climatic events such as droughts, heatwaves, floods, storms, and soil degradation (Olabanji *et al.*, 2021). The projected impact on agricultural production can jeopardize the food security amongst the population and increase the risks of poverty traps for the most vulnerable (Mukasa, 2016; Olabanji *et al.*, 2021). Although the structure of the agricultural sector in the country is dualistic as it compromises both well-developed commercial farmers and the resource-poor smallholder farmers (SHF) (Gwebu & Matthews, 2018), existing literature has indicated that climate variability and change will bring about substantial welfare losses to SHF because of their dependence on rain-fed agriculture and other related socio-economic constraints (Asrat & Simane, 2018; Harvey *et al.*, 2018; Williams *et al.*, 2018). These reasons, coupled with the heavy reliance on traditional irrigation techniques, will undermine any progress toward poverty alleviation, food security, and sustainable development (Elum *et al.,* 2017; Harvey *et al.*, 2018; Ubisi *et al.,* 2017). This results in smallholder farming rarely exceeding the levels of subsistence farming. The uncertainties in climate change scenarios will continue to make it difficult for SHF to make informed decisions, despite having vast traditional knowledge accumulated over generations (Murken & Gornott, 2022). Therefore, smallholder farming which is estimated to occupy only 100 000 ha of the 1.3 million ha of land under irrigation, should undergo a significant transformation to meet the intertwined challenges of achieving food security, reducing poverty while responding to climate change without depletion of the natural resource base (Williams *et al*., 2015; Moyo, 2016). Climate-smart irrigation technologies (CSIT) which is an essential, integral component of climate-smart agriculture (CSA), have been identified as one of the critical responses that would assist in meeting the simultaneous changes of climate change and variability because of its potential to improve resilience and enhance agricultural production (Mazibuko, 2018; Kaptmer *et al.,* 2019; Batchelor & Schnetzer, 2018). However, despite the potential of these technologies, its impact continues to be constrained by the low adoption rate. Theoretical and empirical explanations have linked the low adoption of CSIT to various socio-economic constraints being faced by the smallholder farming community. Therefore, to ensure that SHF can tap into the opportunities provided by CSIT, this study aims to identify the challenges responsible for the disappointing adoption rate amongst SHF, particularly in the Limpopo Province. The history of extreme weather conditions such as drought had significant negative impacts on crop production, food security, and livelihoods of those residing in the rural areas.

4.2 CSIT adoption challenges

Challenges can be defined as factors, conditions, or obstacles that reduce the effectiveness of adaptation strategies (Yameogo *et al.,* 2017). Chappel (2018) indicated that identified challenges that usually form at many different stages of adoption could overlap and interact across different spatial or temporal scales, further creating complex adoption challenges. James *et al*. (2015) classified challenges that prevent the adoption of CSIT into two broad categories: hardware challenges (including physical inputs such as land; human resources; equipment; infrastructure, and finances) and non-physical or software challenges (institutional, cultural, policy and regulatory environment; information, knowledge and skills; technologies and innovations; and governance among others). Existing literature on challenges affecting the adoption of CSA practices indicated that lack of adequate financial capital, lack of information, lack of access to water, labour shortages, and low availability of the necessary agricultural resources were the main challenges of adoption (Yameogo *et al*., 2017). Descheemaeker *et al*. (2016) and Fusco *et al*. (2020) reported that significant organizational challenges such as poor community organization and malfunctioning extension services limit the potential for adoption because they usually result in a poor flow of information, knowledge, and skills. In contrast, Bjornlund *et al*. (2017) argue that challenges that prevent adoption are a broad and complex mix of institutional, market, infrastructure, and production issues. This study has discussed five challenges associated with a low adoption rate. These challenges were also summarized in Table 4.1.

Lack of adequate knowledge and awareness

In most cases, the arrival of new technologies is often met with resistance by agricultural producers. The agricultural knowledge system is built on long-standing cognitive, social, and institutional processes that are difficult to change (Mgendi *et al.,* 2019). According to Shaw (2014), when farmers have access to reliable information on agricultural operations, it would influence their decision to adopt by shaping attitudes towards and awareness of available technologies. Awareness is considered an essential phase in the innovation-decision process. This is where the individual farmer acquires knowledge of the new agricultural technology through communication channels (Owusu, 2020; Cheteni, 2014). However, in some rural communities, lack of knowledge has been identified as a barrier because farmers do not have access to the appropriate information or cannot fully utilize existing information (James *et al.,* 2015). This could result from the fact that communication channels, which are very influential during the initial stages of adoption, maybe inadequate (Cheteni, 2014). Yang *et al.* (2021) indicated that during the early stages of agricultural technology diffusion, only a small number of farmers are willing to try out the technology, while the majority are in a state of “wait and see”.

Unlike commercial farmers who have the luxury of accessing websites, publications and specialists for information, SHF often have difficulty accessing the information on time (Mdlalose, 2016). For decades, SHF has had the assumption that extension officers are the best source of information on farming operations; however, this is incorrect because some of them lack the skills and knowledge to advise farmers on their actual needs and interests (Wheeler *et al.,* 2017; Nakawuka *et al*., 2017). This is consistent with the findings of von Loeper *et al*. (2016), who indicated that in some rural parts of the KwaZulu-Natal province, the educational levels of extension officers were low, and SHF was only visited once a year. In Nigeria, climate-smart practices such as water harvesting were at a low rate of 15% due to weak agricultural service delivery (Kehinde *et al.,* 2022). Therefore, for the newly introduced technologies to be adopted, key stakeholders should make good choices concerning their resources and understand the needs of their primary clients, the farmers (Nakawuka *et al.,* 2017; von Loeper *et al.,* 2016).

Lack of access to finance and credit

Financial challenges refer to having inadequate capital to invest in equipment, infrastructure, installation costs, maintenance costs, land, labour, and other farm inputs required to adopt CSIT (Chappel, 2018; Fish, 2016; James *et al.,* 2015). Kaptymer *et al.* (2019) and Wheeler *et al.* (2017) indicated that SHF usually faces the challenge of managing risks associated with the high costs (at least initial costs), implementation costs, the presence of transactional costs, the uncertainty of returns, and results of adopting new technologies. Unfortunately, capital-intensive technologies are more affordable to commercial farmers, who are often successful and profit-oriented (García *et al.,* 2020; Gwebu & Matthew, 2018; Kinyangi, 2014)**.** In comparison, the SHF are often unemployed and social welfare-dependents who cannot invest in agricultural technologies to improve crop production (Mkuhlani *et al.,* 2020). Although, in the past, the South African government has made efforts to assist SHF finically by investing approximately 2 billion rands, which is equivalent to approximately R40

000 ha^{-1}, from public resources, in establishing, revitalizing, and rehabilitating smallholder irrigation schemes that use CSIT (Fanadzo & Ncube, 2018). The majority of the established schemes have collapsed due to poor performance (Fanadzo & Ncube, 2018). Due to that, the success of CSIT requires enough surplus income to pay for maintenance and management of infrastructure, limited access to financial capital would result in SHF not being able to make significant investments to improve production on their farms (Kamara *et al*., 2019; *Bjornlund et al.,* 2017). According to Kamara *et al.* (2019) and Mzuyanda (2017), in some cases, this challenge is beyond farmers' control as financial institutions are often reluctant to assist SHF because of the risk, interest rates, and challenging tasks associated with high transaction costs. This concurs with Mashnik *et al.* (2017), who reported that financial institutions usually do not finance SHF whose creditworthiness is reduced due to the seasonality and unpredictability of their cash flows. Mdemu *et al.* (2017) indicated that, unfortunately, this has led to farmers drawing from their savings, borrowing from family, or relying on informal loans, which often have unfavourable conditions such as high-interest rates. Mutero *et al.* (2016) reported that credit institutions would instead provide finance to farmers who fall within the economically active age group. Nakawuka *et al.* (2017) and Mvelase (2016) added that financial institutions usually prefer SHF to have collateral such as a title deed to their land to facilitate access to credit; however, the major problem with collateral is that only a small number of farmers possess it.

Insecure land tenure

Access to land for agricultural purposes has been identified as an essential resource playing a crucial role in farmer productivity and income-earning potential in rural areas (Mzuyanda, 2017). Murken & Gornott (2022) indicated that land also shapes the farmers' social relations and identity and is often deeply intertwined with cultural practices. However, farmers' access to and security over land is often managed under statutory or customary land tenure systems, whereby the land tenure rights are primarily influenced by economic, political, and institutional policies and traditional local norms

(Akugre, 2017). Tenure security has been identified as "the right to use, control, and transfer land (Oyetunde-Usman, 2022). In the agricultural sector, tenure security presents several advantages, such as freedom from expropriation, land use as collateral, and the possibility for gains from trade (Fanadzo & Ncube, 2018; Murken & Gornott, 2022). Despite the importance of land, insecure land tenure is still a significant challenge that has resulted in under-developed agriculture and degraded natural resources in most Sub- Saharan African countries (Museli, 2017). Thus, discouraging farmers from investing and making sustainable improvements vital for agricultural productivity (Mzuyanda, 2017). Akugre (2017) pointed out that in Ghana, where customary land tenure remains the significant land ownership, women are often overpowered by men in making land decisions. Thus, increasing inequality among the women in terms of decision making and access to land because of customary norms that are more favourable towards men (Akugre, 2017). Oladele & Mudhara (2016) supported these findings by indicating that in the North-West province, women tend to have smaller landholdings that are less fertile, and these are often accessed through their male relatives. Maluka (2017) added that in some communal areas in South Africa, land tenure insecurity is experienced when development projects are proposed. While the agricultural sector in Malawi has lost approximately 11 million USD per annum in output due to insecure access, use and ownership of land (Emmanuel, 2020).

On the other hand, landowners tend to fear that farmer-tenants or prospective investors could make claims over their land, resulting in a reluctance to securely allocate land (Mansaray *et al.,* 2019). This is consistent with the findings of Fanadzo & Ncube (2018), who explained that some landlords in the Eastern Cape did not feel secure enough to lease land due to the fear of losing their land and preferred to take it out of production. However, decisions to leave vast land uncultivated will not only leave landless farmers full of uncertainties over land ownership through rental and sharecropping; it can also be discouraging to prospects of young farmers who would have committed resources to make a living from the investment in improved management practices (Fanadzo & Ncube, 2018; Mansaray *et al.*, 2019; Murken & Gornott, 2022). However, Persha *et al.* (2015) mentioned that it is still unclear to what extent insecure land tenure acts as a fundamental challenge to climate-smart agricultural practices across different socio-economic, institutional, biophysical and related contexts. However, with the support of international experts and donor organisations, the governments have tried to resolve issues related to insecure land tenure by implementing a land reform programme for decades. These efforts have often been proven to be ineffective, slow, and even harmful because they do not give attention to providing farmer support services to land reform beneficiaries (Mzuyanda, 2017; Murken & Gornott, 2022).

Limited access to agricultural training

Agricultural training can be described as a skills empowerment process designed to enhance an individual's knowledge, skill, and competencies to improve his/her performance regarding farming operations in the field (Tshwene, 2019). In most cases, extension officers play an essential role in creating awareness through demonstration plots on the farmers' fields, workshops, and farmers' day to spread knowledge and benefits of new technologies (Okunade & Adekalu, 2019; Bjornlund *et al.*, 2020). Miheretu & Yimer (2017) added that the knowledge that farmers gain through training enables them to be equipped with the technical know-how required for implementing agricultural technologies and make assists them in realizing the long-term benefits through sustainable production and land management practices rather than immediate benefits obtained at the expense of soil quality. This is in agreement with the findings of Uyetunde-Usman (2022), which indicated that in Tanzania, improved adoption rates of agricultural technologies had occurred first among trained farmers that rose steadily over the years among intermediate and ordinary farmers. Therefore, training can be considered a vital tool required in using technology in irrigation, which is known to lead to increased farm production where SHF produce sufficient food to eliminate food insecurity, provide opportunities for labour, and form the basis for broader-based rural areas growth (Ndlovu, 2013).

According to Maziya (2013), farmers' training also moves beyond agronomic practices and encompasses their abilities to negotiate better markets output prices. Although training has been positively linked to the adoption of agricultural technologies, only a small group of farmers often could take the technical training during the early stage due to various challenges._According to Kalkidan (2016), there is often low participation of women in training programmes in some communities as they are often prohibited from speaking up and taking part in discussions during training because their cultural norm expects them to be silent in front of their male counterparts. Due to the fact that the technology is new to ordinary farmers, the essential requirement is that farmers invest time and energy to understand it by learning (Yang *et al.*, 2021). However, some are often tied up in domestic duties and hardly have the time. Other problems are related to the fact that there has been a decline in the quality and quantity of extension officers in South Africa over the past years. Extension workers are hardly afforded in-service training year after year and are poorly linked to research. Thus, it results in situations whereby the disseminated information to the majority of their audience becomes technically redundant and obsolete. While the remaining extension officers were characterized as poorly trained, providing top-down service, and not adapting to technological changes that would allow them to effectively impart training to farmers (Fanadzo & Ncube, 2018). Thus, results in situations whereby the disseminated information to the majority of their audience becomes technically redundant and obsolete (Kinyangi, 2014). These shortcomings can be solved by implementing social learning platforms such as farmers-to-farmers extension services, whereby key farmers are trained and are meant to diffuse technologies to the rest of the farmers through learning from key farmers or neighbours (Uyetunde-Usman, 2022). As farmers who can attend training in the most remote locations may acquire stronger networks with their fellow farmers in their locality and extension officials after they return, they are often excited to showcase what they have witnessed during the training (Pratiwi & Suzuki, 2020). Collaboration with non-governmental organizations, researchers, donors, and local communities can also assist in easing the pressure on extension officers.

Lack of infrastructure

When SHF decide to adopt CSIT, they need to have the associated infrastructure and complementary inputs as their absence may generate a barrier to adoption in that region (Wreford *et al*. 2017). According to Nakawuka *et al.* (2017), in some countries, farmers are supplied with good water sources that can be used for agricultural production; however, infrastructure to facilitate these water sources for irrigation is often missing or inadequate. In cases where SHF from rural communities are provided with the required infrastructure and inputs (irrigation pipes, generators, pumps, Jojo tanks) for CSIT adoption by the government, they often fail to take care of the infrastructure. A study by van Koppen *et al.* (2017) revealed that in the Limpopo Province, where irrigation takes place in the form of irrigation schemes, infrastructure such as (canals, reservoirs, micro-jets/sprinklers, storage/sheds, fences, etc.) were not utilized until they were vandalized, while some remained in poor condition. Fanadzo & Ncube (2018) and Nakawuka *et al.* (2017) indicated that one of the primary reasons for the poor condition might be that governments and other external agencies often construct smallholder irrigation schemes (SIS) infrastructures without fully involving SHF. This has resulted in SHF not investing in these SIS by avoiding payment for maintenance costs, thus leading to their deterioration with time (Nakawuka *et al.*, 2017).

Table 4-1: Overview of the main challenges identified in the literature.

Challenges	Description	Sources
Limited knowledge and awareness.	Inaccurate information, farmers' level of education, lack of appropriate CSIT information dissemination, conflict with traditional knowledge and lack of extension services.	Myeni *et al*., 2019; Mutero *et al*., 2016; Fanadzo & Ncube, 2018; Wamalwa, 2017; Harvey *et al*., 2017; Nakawuka *et al*., 2017; James *et al*., 2015; Popoola *et al*., 2020; Lebeta, 2017.
Lack of finance and credit.	High initial cost, high implementation cost, hidden cost (transactional cost, uncertain returns and maintenance cost.	Wheeler *et al*., 2017; Yameogo *et al*., 2017; Kaptymer *et al*., 2019; Bjornlund *et al*., 2017; Chappel , 2018; Fish, 2016; James *et al*., 2015; Mdemu *et al*., 2017; Mashnik *et al*., 2017; Nakawuka *et al*., 2017, Mvelase, 2016; García *et al*., 2020.
Insecure land tenure.	Lack of title deed, the insecure land tenure system, land fees and unpredictable landowners.	Mzuyanda, 2017; Fanadzo & Ncube, 2018.
Limited access to agricultural training	Lack of required skills to use technologies, lack of capacity building, results/effects of technology challenging to observe, poorly trained extension officers and provision of a top-down approach.	Fanadzo & Ncube, 2018; Fish, 2016; Nakawuka *et al*., 2016; Bjornlund *et al*, 2020**;** Ouédraogo *et al*., 2019; Lebeta , 2017, Wekesa, 2017; Okunade, Awolowo 2019.
Lack of infrastructure	Inability to assess CSIT equipment, lack of reliable water sources, lack of motivation, labour shortages and poor labour supervision.	Murray *et al*., 2016; Kaptymer *et al*., 2019; Mutero *et al*., 2016; Batchelor & Schnetzer, 2018; Mango *et al*., 2019; James *et al*., 2015; Mugwabana *et al*., 2018; Zighe, 2016.

4.3. Materials and methods

4.3.1. Study area, sampling, and data collection

The study was conducted in two districts in the Limpopo Province: Vhembe and Capricorn districts (see Figures 4.1 and 4.2). In each district, four local municipalities were further selected; Thulamela, Collins Chabane, Makhado, and Musina were chosen under the Vhembe district. Polokwane, Blouberg, Molemole, and Lepelle-Nkumpi municipalities were selected in the Capricorn district. The two districts were selected to compare the different agro-ecological zones to understand better some of the likely climatic changes to the district environment and the SHFs' ability to adopt the CSIT. While the selected municipalities have a significant proportion of land used for agricultural purposes.

A total of 100 SHF were surveyed: Vhembe district (N = 50) and Capricorn district (N = 50). Districts within the province were selected purposefully in consultation with local district agricultural offices to ensure the objectivity of survey teams. SHF from each municipality was selected through convenience sampling within each district. SHF was interviewed using a structured questionnaire administered by trained enumerators familiar with local farming systems and customs. The questionnaire includes demographics, farm characteristics, household food security, institutional factors, and entrepreneurship skills. All covid-19 protocols were followed during the field survey.

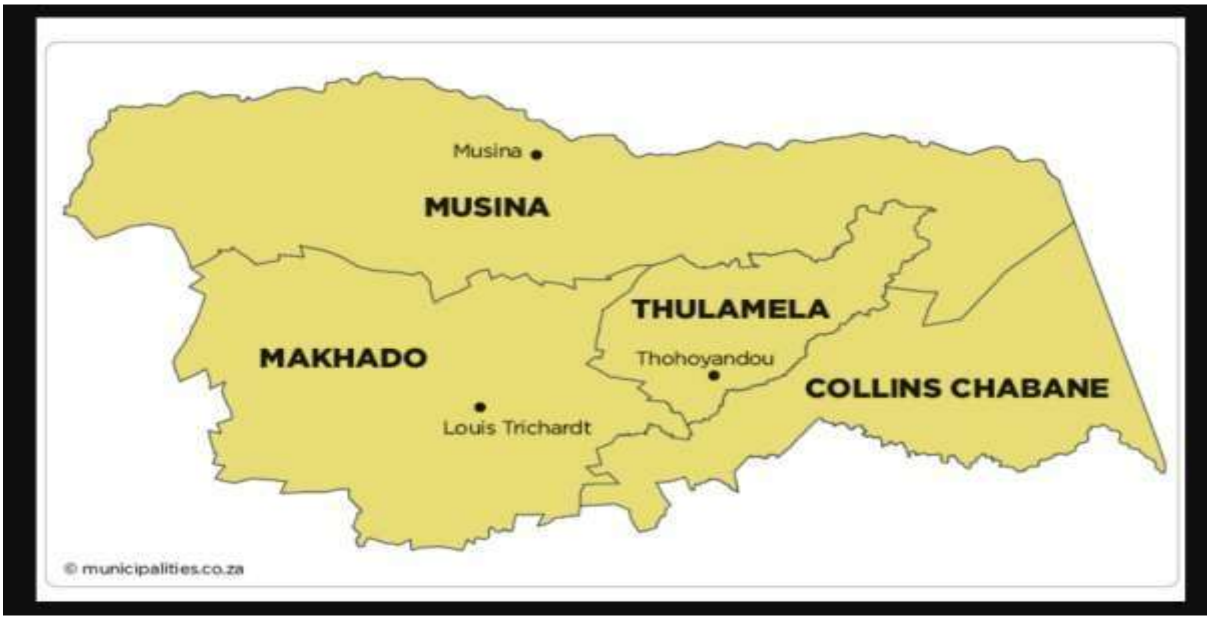

Figure 4-1: Map indicating study areas in the Vhembe district

Source: *(https://en.m.wikipedia.org/wiki/List_of_municipalities_in_Limpopo)*

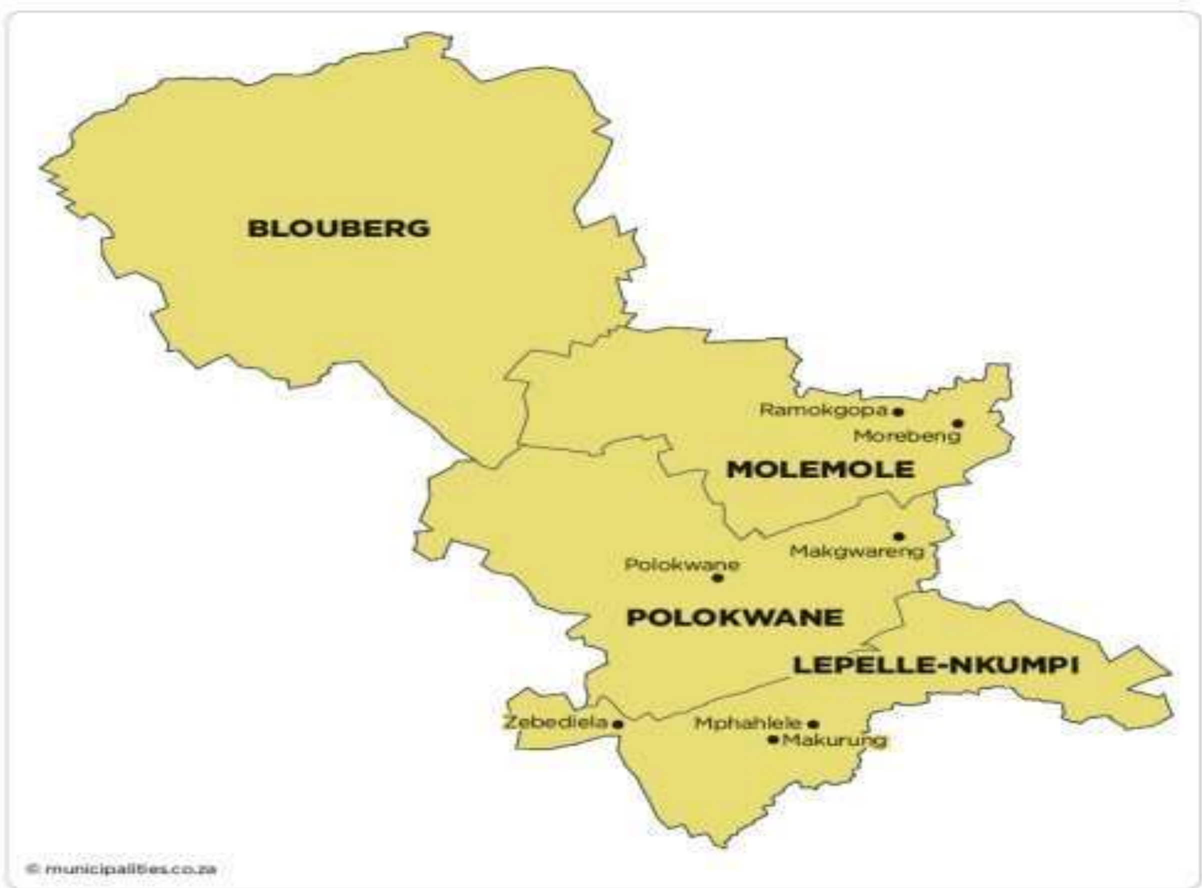

Figure 4-2: Map indicating study areas in the Capricorn district

Source: *(https://en.m.wikipedia.org/wiki/List_of_municipalities_in_Limpopo).*

4.3.2. Data analysis

This study's data collected from the field was edited, coded, and cleaned to ensure consistency, uniformity, and accuracy. The data were entered into the computer for analysis, and Statistical Software for Data Science (STATA) version 15 was used for processing. In order to ensure that the first objective was achieved, descriptive statistics such as frequencies, percentages and tables were used to describe and examine "challenges faced by SHF in adopting CSIT to improve sustainable agricultural productivity" in the Limpopo Province.

4.4. Results and discussion

Knowledge and Awareness of CSIT

The participants' knowledge and awareness of CSIT were assessed by asking whether they had ever heard of these technologies commonly used to assist in adapting to climate change. The results indicated that most of the participants in the two districts were aware and had some basic knowledge of only two CSIT, namely drip irrigation and RWH at different levels (Table 4.2). As 64% of the participants in the Vhembe district reported that they had heard of drip irrigation, 80% of the participants in the Capricorn district had more awareness of the same technology. Awareness of RWH was also high in the Capricorn district at 74%, while in the Vhembe district, it was fair at 50%. Overall, the high level of CSIT awareness amongst the participants in the study area is a significant step toward the eventual adoption of these technologies. In support of the current study's findings, Cafer & Rikoon (2018) argued that when farmers have increased access to information and improved knowledge on the use and potential benefits of technology, it will allow them to properly access and, to some extent, mitigate, the potential risk associated with the adoption of innovations.

Table 4-1: Awareness status of CSIT in the study area.

	Awareness of CSIT			
Technology	**Vhembe**		**Capricorn**	
	n	%	n	%
Drip irrigation	32	64	40	80
RWH	25	50	37	74

However, it has also been pointed out that awareness of CSIT does not necessarily guarantee adoption. Due to that, an emphasis on knowledge alone is short-sighted as the real challenge to adoption is in resource constraints experienced by farmers (Cafer & Rikoon, 2018). In most cases, different farmers often have different absorptive capacities for the agricultural information they require (Yang *et al*., 2021). Thus, leading to the difference in their perception of the technologies and affecting their level of adoption. The study found that although most of the participants were aware of RWH, adoption was extremely low in the two districts (Table 4.3). In the Vhembe district, 6% of the participants adopted the technology, while in the Capricorn district, the adoption level was fairly low because only 8% of the participants used the technology. The low adoption rates of rainwater water harvesting technologies amongst the SHF can result from the difficulties associated with the many combinations of ecological and socioeconomic constraints in the two districts. This indicates the importance of establishing a farmers' understanding and perceptions of CSIT because the final decision to use adaptation strategies, adaptation level and choice among the available adaptation options can be affected by demographic characteristics, agro-ecological setting, socioeconomic factors and other institutional constraints (Gwambene *et al*., 2015; Addis & Abirdew, 2021).

Table 4-2: Adoption status of CSIT in the study area.

	Adoption of CSIT			
Technology	**Vhembe**		**Capricorn**	
	n	%	n	%
Drip irrigation	33	66	41	82
RWH	3	6	4	8

Communication channels used for awareness creation

The study found that participants rely on several ways to receive agricultural information (Figure 4.3). In the Capricorn district, 92% of the participants indicated that agricultural extension workers constituted the most important source of information. While in the Vhembe district, only 34% of the participants relied on extension services to provide relevant information on agricultural technologies. Staff shortages and other related challenges often result in farmer interaction with extension officers being reduced to only once a month or once every two months (Ziba, 2015; von Loeper *et al.*, 2016; Maluka, 2017). These findings contradict Shange (2015) that extension officers play an essential role in creating awareness, organisation, exchange of information and technology adoption among SHF. Therefore, in cases whereby the target beneficiaries are being excluded from the extension process, and a lack of credibility and incentive to transfer information is a prominent causal effect of the poor impact of extension services; farmers may take the initiative to learn from other sources (Yang *et al.*, 2021; Uyetunde-Usman, 2022). Findings revealed that 18% of the participants in both districts resorted to farmer groups to receive their information on irrigation technologies. Whereas other sources of information included friends, which was used by 16% of the participants in the Vhembe district and 10% of the participants in the Capricorn district, while tribal meetings were used as an alternative source of information by 8% of participants in the Vhembe district and 26% participants in the Capricorn district. According to Uyetunde-Usman (2022), social interaction among farmers is a powerful tool for adopting and disseminating agricultural technologies because it naturally enforces trust and behaviour. Furthermore, only a small percentage of 6% in the Capricorn district have been reported to rely on radio. This is inconsistent with Musetha (2016) findings, who found that radio was still the most effective way of reaching rural farmers due to climate change adaptation measures.

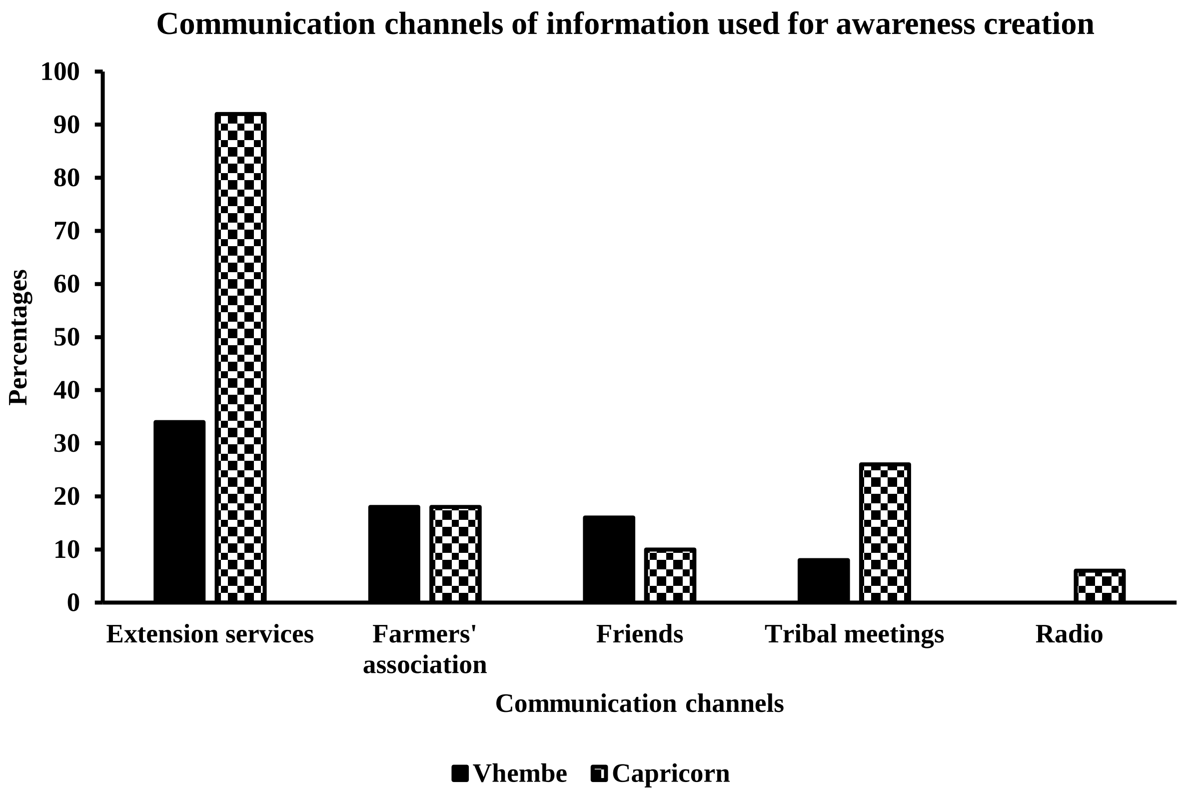

Figure 4-3: Communication channels used by SHF for awareness creation.

Sources of funding for implementing CSIT

Credit availability, either in cash or non-monitory form from government or private institutions, is an essential institutional service for assisting poor farmers with input purchases and ultimately adopting new technologies (Ziba, 2015; Kalkidan, 2016). However, existing literature has ranked poor or no access to formal credit by SHF among the first three challenges after access to land and markets, constraining the development of SHF (Mzuyanda, 2017). Table 4.4 indicates that access to credit through formal institutions is non-existent in the two districts, as 100% of the participants in the Vhembe district and 86% of the participants in the Capricorn district indicated that they have no access to loans. This is because financial institutions have not been able to assist SHF with formal loans due to associated risks such as the inability to provide collateral for loans, interest rates and difficult tasks associated with high transaction costs (Moyo *et al.*, 2016; Mzuyanda, 2017). Some problems may be related to the repayment of the loans, particularly after a poor harvest (Awinda, 2018). Thus, some farmers either avoid farm credit or borrow money from friends, family, and informal lenders to meet their financial obligations. Findings also showed that 63.27% of the participants in the Vhembe district and 36% of the participants in the Capricorn district were often hesitant to use their own money for investing in agricultural technologies, as the majority of them are dependent on government support such as social grants child grants, pensions, old age grant and disability grant as a supplementary source of income. Therefore, in such situations, it is widely expected that participants would resort to government institutes such as the Limpopo Department of Agriculture to ease the financial constraint associated with the adoption of innovations. In this study, 81.63% of the participants in the Vhembe district and 82% of the participants in the Capricorn district pointed out that they have received funding in the form of inputs for the past 12 months. According to Baloyi (2010), partial funding is often regarded as a fruitless expenditure, particularly for poor SHF whose financial resources complement the on-farm infrastructure provided by the government.

Table 4-3: Sources of funding used to support SHF in adopting CSIT.

Support	District			
	Vhembe		Capricorn	
	n	%	n	%
Formal credit	50	100	43	86
Own support	31	63.27	18	36
Government Funding	40	81.63	41	82

Land tenure arrangements

To understand why the majority of the participants had no access to credit and the low adoption rate of CSIT, it was necessary to examine the land ensure systems in the two districts because the land is among the essential asset required for agricultural production. Figure 4.4 shows that in the Vhembe district, 32% of participants acquired land through allocation by the chief, 8% bought the land, 16% through inheritance, 28% were leasing, and 16% mentioned other ways in which they acquired the land, such as farming under a communal land, projects ran by the municipality allocating participants land or borrowing from a friend. While in the Capricorn district, 28% had access to land through allocation by the chief, 8% bought the land, 16% had access to land through inheritance, and 20% were under a lease. In comparison, 16% were classified under the “other” group. The results are in line with Maluka (2017) findings which indicated that a larger proportion of farmers sought permission from the chief to occupy land due to the customary land allocation system.

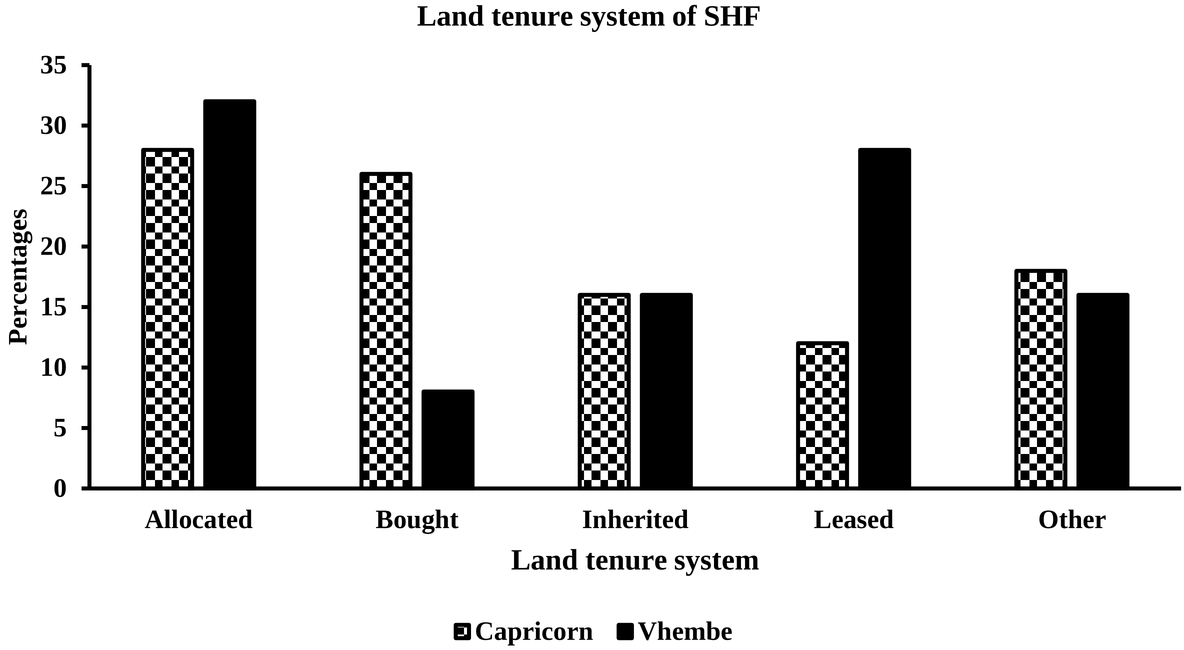

Figure 4-4: Land tenure systems of SHF

Evaluation of SHF's satisfactory level concerning the security and decision-making process under the current land tenure system

The study also evaluated whether farmers were satisfied with the present land tenure security (Table 4.5). The results revealed that 76% of the participants in the Vhembe district and 64% in the Capricorn district are least satisfied with the present security of their land tenure system. According to Murken & Gornott (2022) and Oyetunde-Usman (2022), when farmers' land tenure arrangements are communal under traditional leadership, it will not only constrain farmers' ability to use their land as collateral for credit; it could also trap populations affected by disasters and impede them from migrating into safe areas, where they fear to lose the claim to their land, and it can fuel conflict over land and the resources tied to it. This was supported by Fanadzo & Ncube (2018), who added that farmers who are on quitrent (pay rent to the magistrate) and right to occupy (communal under traditional leadership) land tenure arrangements have no sense of ownership and hardly invest in new technologies. While only

22% of the participants in the Vhembe district indicated that they find it challenging to make land-use decisions because of the land tenure system. This can be attributed to the participants renting land because they are often reluctant to invest in agricultural technologies due to the fear of being evicted in the future (Ndlovu, 2013; Mansaray *et al.*, 2019). The findings are in agreement with Zeng *et al*. (2018), who pointed out that insecure land tenure systems discourage agricultural technology adoption, while farmers with secured land rights were more likely to invest in soil-improving and natural resource management practices, which will have a positive effect on agricultural production and productivity.

Table 4-4: Satisfaction level of security of land ownership and decision making.

	District			
	Vhembe		**Capricorn**	
	n	**%**	**n**	**%**
Satisfied with the present security of ownership	38	76	32	64
Find it challenging to make land-use decisions due to the land tenure system.	11	22	0	0

Assessment of SHF agricultural skills

Access to training

Agricultural training has been described as an effective channel in which farmers are equipped with the information and technical know-how required to adopt relevant technologies (Pratiwi & Suzuki, 2020; Miheretu & Yimer, 2017). However, from the survey, only 16% of the participants from the Capricorn district and 36% of participants from the Vhembe district had undergone training (Figure 4.5). While 84% of the participants in the Capricorn district and

64% of the Vhembe district had no access to any related agricultural training. Lack of training amongst participants is often a result of several reasons, such as participants thinking that they have more experience than the service provider, age can also be another factor as older participants often do not have the strength to attend training, the education level of the participants is often not taken into consideration during the planning phase thus resulting in them being stuck with pamphlets having guidelines they cannot read. While others do not even know where such training is being offered in the study area.

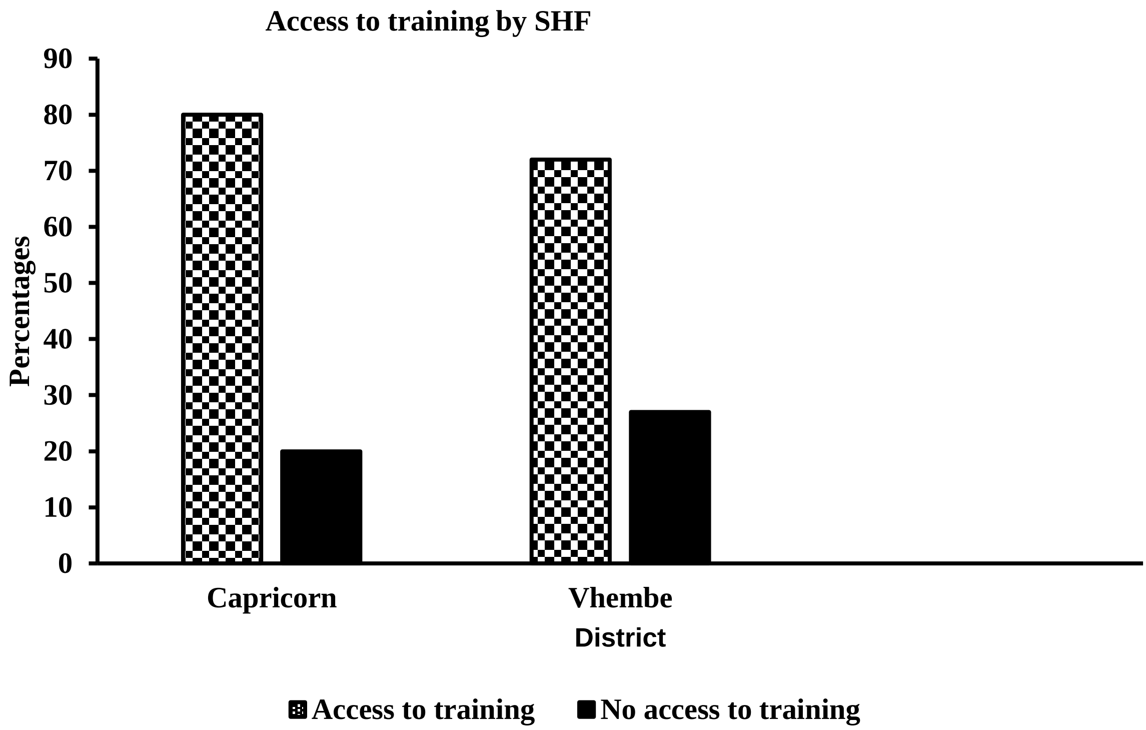

Figure 4-5: Comparison of SHF access to agricultural training.

Types of training programmes attended by SHF

Training of farmers that is received either theoretical (textbook, oral presentation) or applied (demonstration, on-farm trial, farmer field day) is an essential tool in assisting farmers to overcome complexities that are associated with the use of the technology and accurately assessing its advantages and ability to meet the farmers' needs (Cafer & Rikoon, 2018).

Tshwene (2019) mentioned that an effective training programme requires a clear picture of how the trainees will need to use the information after training in place of local practice and what they have adopted before in their situation. In this part, the study wanted to examine the various training programs carried out in the study area. Findings in Table 4.6 indicate that 40% of the participants in the Vhembe district and 60% of the participants in the Capricorn district attended farmer's field day, 42% of the participant in the Vhembe district and 62% of the participants in the Capricorn district acquired their skills through the attendance of a workshop/seminars. While the attendance of agricultural short courses was low in both districts because only 4% of participants in the Vhembe district and 10% of participants in the Capricorn district indicated that they have registered with an institution of higher education to improve their knowledge and skills. The low attendance resulted from the fact that formal training often depends on the participants' literacy level, and more theory than practical is used as the teaching method. Thus, participants end up having supporting materials which they cannot use. Whereas informal training programmes such as farmer's field days are more effective because participants can observe the use of agricultural technologies through practical demonstrations.

Table 4-5: Types of agricultural training programmes undertaken by SHF

Training programme	**District**			
	Vhembe		**Capricorn**	
	n	**%**	**n**	**%**
Farmers field day	20	40	30	60
Workshop/seminar	21	42	31	62
Agricultural short courses	2	4	5	10

Despite the attendance of these different agricultural programmes, it has been revealed that some of the training programmes that the participants attended were not intensive enough to improve their agricultural skills and knowledge. This resulted in the study assessing the competence of participants in a range of agricultural skills: production, marketing and business management. Figure 4.6 revealed that 60% of the participants in the Vhembe district and 18% of the participants in the Capricorn district indicated that they still require additional training on crop production skills such as irrigation scheduling and frequency, determining intra and inter-row spacing, application of herbicides and fungicides and fertilizer application which are critical as the inappropriate application of these skills could negatively affect yield and hence the livelihood of farmers. Although the participants in the two districts face marketing challenges, there seems to be no training provided in this regard. As 40% of the participants in the Vhembe district and 68% of the participants in the Capricorn district indicated that to get a return on their investment, it is essential to be trained in marketing skills such as price determination, knowledge of the market for produce and packaging required for marketing their product. Whereas 34% of the participants in the Vhembe district and 58% of the participants in the Capricorn district pointed out that training on the appropriate application of business skills such as financial management would enable them to be managers of their finances.

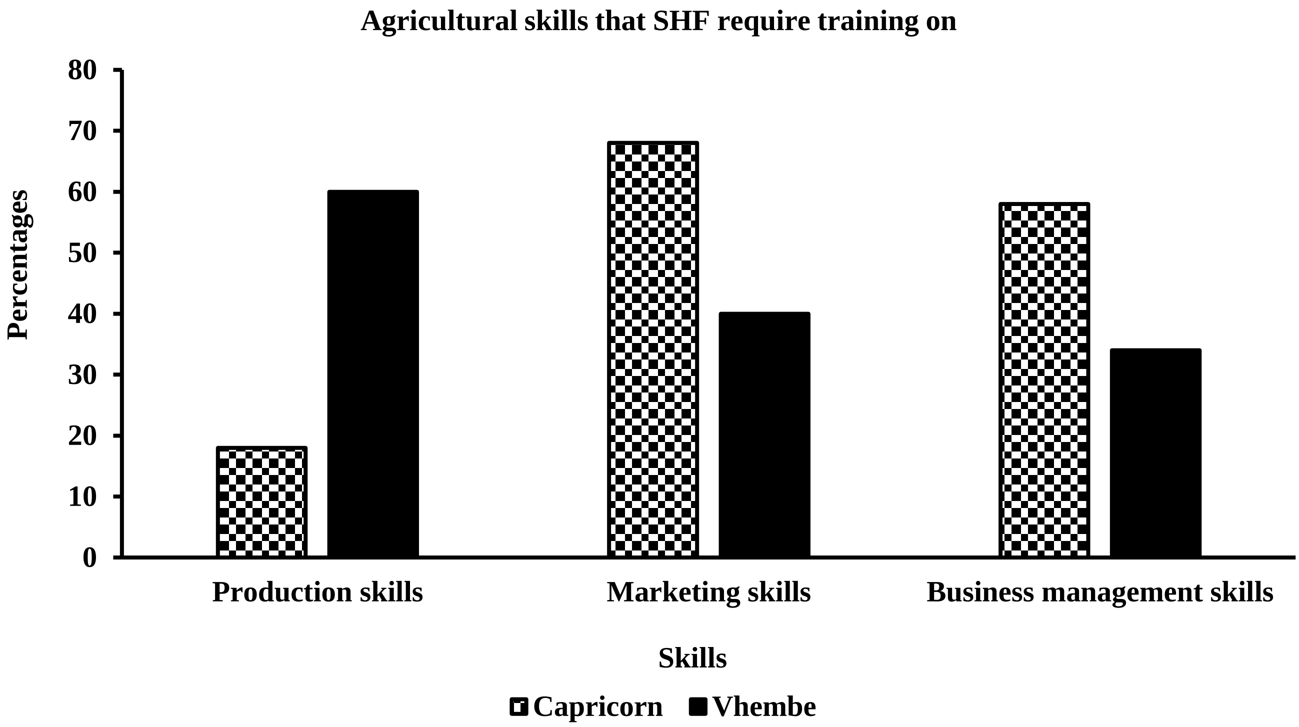

Figure 4-6: Agricultural skills that SHF in the two districts require training.

4.5. Summary

Understanding the impact climate change and variability have on SHF's productivity is crucial for ensuring food security and poverty reduction in Sub-Saharan Africa. This study assessed the challenges affecting the adoption of CSIT by SHF to improve sustainable productivity in the Limpopo Province. One of the biggest challenges facing SHF is limited access to knowledge and awareness, the initial step toward technology adoption. Although the results have revealed that SHF from the two districts had some basic knowledge of the existence of CSIT, such as drip irrigation and RWH, the adoption rate of the technologies remains significantly low. Despite the widespread evidence of economic and environmental benefits that have been associated with these technologies. This is because most farmers were keen on adopting drip irrigation, however, they lacked the personal finance to pay for it. Most could also not risk taking it on credit because they do not hold a title deed to their farmland due to the land tenure system. Support from the government regarding input or finance is often a temporary solution. This is a clear indication that knowledge may be essential but how farmers receive it from the different sources has a more significant effect on adoption. Farmers would know that when they do not have enough capital to finance the implementation of drip irrigation, conservation methods such as mulching would be the best solution.

Furthermore, the limited access to agricultural training has resulted in the farmers not having access to sufficient production skills. Although extension officers constitute a significant source of information for SHF, it has the potential to improve the competency level in agricultural skills and knowledge. This has not been the case in the two districts because, due to being understaffed and having a shortage of other related resources, the interaction between extension officers has been reduced from once a week to once or twice a month. Such interactions have become a clear indication that the production challenges faced by farmers are not likely to be addressed with the current support provided by the government. Addressing these challenges could lead to smallholder farming in the Limpopo Province, contributing to economic growth and development. Therefore, designing an effective and well-coordinated extension programme is key to agricultural development and yield performance. In such programmes, farmers should be given a platform to be involved in the planning process for the sustainable adoption of innovation and technologies. Agricultural training should have a combination of both indoor courses and field instruction. Having a combination of literate and illiterate SHF allows them to learn from one another. Lastly, setting up communication channels between SHF and trainers will ensure that they assist one another with problems associated with agricultural cultivation.

CHAPTER 5: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Summary

The main objective of this study was to investigate challenges affecting the adoption of CSIT by SHF to improve sustainable productivity. The specific objectives were to identify challenges SHF face in adopting CSIT and determine socio-economic factors influencing the adoption of CSIT. Descriptive statistics were employed to assess the challenges preventing SHF from adopting CSIT. The leading descriptive indicators employed were percentages, frequency, and mean values. The results were presented in tables. The binary Probit regression model was used to test the factors that influence the adoption of CSIT. In comparison, the OLS model was used to test the factors that influence adopting of CSIT.

5.2. Conclusions

Three conclusions emerge from the analyses of the three objectives:

1. The CSIT currently used by SHF in both districts are drip irrigation systems and RWH technologies. The descriptive results indicated that adoption was higher in the Capricorn district (73.91%) than in the Vhembe district (26.09%). This has also revealed that most of the SHF in the Vhembe district still rely on TMI or rain-fed agriculture.
2. The empirical results indicated that CSIT adoption was positively influenced by gender, age, household size, district, farm size, staple food production, and knowledge. This observation provides a broader spectrum of interventions to improve the adoption of CSIT.

3. The key finding was the challenges preventing SHF from adopting CSIT are lack of knowledge, finance, insecure land tenure systems technical skills, and infrastructure. However, these challenges affect the SHF differently in each district.

5.3. Recommendations

Key stakeholders such as the Limpopo Department of Agriculture, research institutions and non-government institutions have done a very good job in assisting participants with extension services, financial and it has the potential to contribute a lot to the livelihood of its citizens as much as food security, food self-sufficiency and job creation is concerned. However, converting the area's agricultural potential to real production tends to be something not easy to do. Throughout the study, challenges associated with the adoption of CSIT were identified, and the following recommendations arose:

- According to the study findings, gender played a significant role in the adoption of CSIT among the participants. This is a clear indication that government and other related agencies should focus their efforts on raising awareness and breaking the male dominance in CSIT adoption in the study area. This can be accomplished by implementing interventions and initiatives that encourage women's adoption of CSIT by providing equal opportunities, resources, and awareness.
- The participants' average age indicated a high level of non-youth participation regarding CSIT in the study area. Although, the dominance of older participants may be an advantage because they often have vast indigenous knowledge and experience in farming activities passed on from generation to generation. Unfortunately, the future of agriculture lies in the hands of the youths. To ensure that more young people become interested in the adoption of CSIT, the smallholder

farming sector needs to be made more flexible and accessible for the youths. Agriculture through the use of CSIT can be used to tackle youth employability challenges, particularly in the study area, by focusing on proper awareness, capacity building, and partnership aimed at increasing youth participation in mainstream agriculture.

- Despite the fact that most participants were aware of CSIT, the adoption level of low-cost CSIT such as RWH and mulching were extremely low or non-existent. This is often a result of poor access to relevant information from the source of information, which is the extension officers in most cases. Although most of the participants in the Capricorn district indicated that they had access to extension services, the Vhembe district frequencies of extension services were very low. Thus, participants end up relying on other sources of information, which may sometimes provide them with inaccurate information. Due to that, extension services can be a useful source of information as it plays an essential role in empowering participants with farming knowledge, techniques and skills; revitalizing the existing local agricultural extension service delivery would be the first step to remedy the knowledge and skills gaps of extension officers to participants. This action will improve the awareness of extension and advisory services delivery within the district and improve the quality of communication with farmers. In addition, providing extension officers and research stations with the capacity, support, and physical means to expose participants to CSIT through demonstrations and training will help to increase the adoption of CSIT.
- The slight difference in farm income per season between adopters and non-adopters raised some concerns. As one would expect that by adopting CSIT, SHF would have the advantage of producing more than its counterparts. However, it has been

indicated that the non-adopters have more farming experience than the adopters and CSIT such as drip irrigation are often associated with very high operational and maintenance costs, particularly at the initial stage. Thus, more emphasis needs to be placed on suitable technologies for the participants' socio-economic status. For instance, adopting organic mulching such as straw will enable resource-poor participants to experience the full benefits of moisture conservation at an extremely low cost. Therefore, increasing participants' knowledge through better access to technical information, extension and training will help them develop a positive economic assessment of CSIT.

- Lastly, access to more flexible financial and credit sources is often a significant challenge among participants in the two districts. Without access to finance, participants cannot invest in essential production inputs and equipment that will ultimately aid in increasing CSIT adoption. Although, various stakeholders, particularly the government, have assisted participants financially by providing them grants and subsidies. It is often not enough to hand out these funding sources as they end when the project is discontinued. Unfortunately, land cannot be used as collateral to gain access to credit as most participants operate under a communal land system that does not guarantee landholding rights. Therefore, the government could mainly introduce agricultural finance institutions in rural areas to assist participants since other financial institutions like banks may have strict requirements in providing loans such as collateral that the participants may not have.
- Furthermore, collaboration with the private sector will assist in providing agricultural inputs at affordable prices and facilitate any business components involved in the adoption of CSIT. This will also minimize the participants' dependence on government institutes for any subsidy and maximize the use of the already limited

resources. As affordability and availability are essential for CSIT adoption. This could only be achieved when core decision making at lower and local structures is strengthened to ensure smooth delivery of CSIT services.

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APPENDICES

APPENDIX A: QUESTIONNAIRE

The purpose of this questionnaire is to evaluate the challenges affecting the adoption of climate-smart agricultural practice irrigation systems and the productivity of SHF in the Limpopo Province, particularly in the Vhembe and Capricorn districts. The information of each participant will be managed privately. Please use an X next to the code to answer the questions where appropriate.

Should you feel uncomfortable answering any question, please leave the item blank and answer the next question.

INTERVIEWER DECLARATION:
I, ……………………………………………………………………………………………
Declare that I will ask for this questionnaire as it will be laid out. I declare that all responses recorded will be the true responses of the respondent and that I have thoroughly checked the questionnaire.
Signature: ………………………………………………………………………

Date: ………………………………………………………………………………

PART 1. DEMOGRAPHICS

1.1. Gender (*Please tick the correct option*)

Male	Female

1.2. Age (in years) ....
1.3. Marital status (*Please tick the correct option*)

Single	Married	Divorced	Widowed

1.4. Farmers' highest educational level (*Please tick the correct option*)

No formal education	Primary School	High School	Tertiary level	Other (specify)

1.5. How many people are in your household (number)..

1.6. Who is the head of the household?

Child	Father	Mother	Grandmother	Other(specify)

1.7. How much is your household total non-farm monthly income (in rands) ....

1.8. How many people in your household receive non-farm income? ....

PART 2: FARMER CHARACTERISTICS

2.1. Who is involved in farming?

Child	Father	Mother	Grandmother	Other(specify)

2.2. How long have you been farming?..Years

2.3. What is your primary objective for farming? (*Please tick the correct option*)

Household consumption	Home consumption and selling	Selling

2.4. What is your primary farming activity? (*mention any primary farming activities you are engaged in*)

....

2.5. Which farming system do you use? (*Please tick the correct option*)

Dryland	Irrigated land	Both

2.6. What is the total area of land your household owns/operates?

Irrigated land..............ha Dry land..........ha

2.7. How much land was cultivated in the past 12 months?
Irrigated land ....ha Dry land......................ha

2.8. Indicate the number of plots you have, their sizes and the means of ownership by completing the table below (Include both irrigated and dryland plots if irrigator)

Plot number	**Size of a plot (ha)**	**Means of ownership**	**Farming practice**	**Land fees paid for the plot per year**
1	**1**	**3**	**1**	
2	**2**	**3**	**1**	
6	**0.5**	**3**	**1**	
1=Maize 6=Cabbage 2=Tomatoes 7=Beans 3=Potatoes 8=Onions 4=Sugarcane 9=Butternut 5=Spinach 10=Other (specify)……………………..	Means of ownership 1=Allocated 2=Bought 3=Inherited 4=Borrowed/leasing 5=Other (Specify)		Farming practice 1=Irrigated 2=Dryland	

2.9. How much is your total farm income per season in rand? ....

2.10. Do you find it difficult to make land use decisions due to the land tenure system?

Yes ☐ No ☐

2.11. If yes, please specify

2.12. Generally, are you satisfied with the present security of your land?

Yes ☐ No ☐

2.13. Rate the quality of your land for crop production

Poor ☐ Good ☐

Do you have any livestock on your farm? NO

IF Yes, how many?..

Did you employ any labourers at the farm? Yes

If yes, how many permanent labourers?.........1......................................

PART 3: IRRIGATION SOURCES

3.1. What type of irrigation practice are you using? Yes/No ....

3.2. If yes, name the irrigation practice and why you use it? ....

3.3. Do you know any **climate-smart** irrigation practices? Yes/No

3.4. Are you using any **climate-smart** irrigation practice? Yes/No

3.5. If yes, name the climate-smart irrigation practice and why you are using it? ....

3.6. If no, why are you not using it? ....

3.7. Would you want to adopt any **climate-smart** irrigation practice? Yes/No

3.8. If yes, name the irrigation practice and why you would like to adopt it?

....

3.9. If no, why? ....

3.10. Is there any indigenous irrigation practice you are using? Yes/No

3.11. If yes, please mention why? ....

3.12. If no, why are you not using any indigenous irrigation practice? ....

3.13. Which of the following irrigation practice do you know and use?

Know	Use
Watering can/Bucket system	A portable container, usually with a handle and a spout, is used to water plants by hand.
Canal and pipe conveyance systems	A structure that conveys water from one location to another. In most cases, it is from the dam to the watered plants in the field
Sprinkler irrigation systems	A method of applying irrigation water, which is similar to natural rainfall. Water is distributed through a system of pipes, usually by pumping.

Drip irrigation systems	Micro-irrigation system has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface.
Furrow irrigation	The surface irrigation in which trenches or furrows are dug between crop rows in a field. Farmers flow water down the furrows (often using only gravity).
RWH	RWH is collecting the run-off from a structure or other impervious surface to store it for later use. Traditionally, this involves harvesting the rain from a roof.

3.14. Where do you obtain water for irrigation?

Dam	River	Borehole	Taps	Individual tank	Other (specify)

3.15. How is water pumped to reach your irrigation plot(s)?

Gravity	Electricity pump	Diesel pump

3.16. Do you pay any fee for water-related services (diesel or electric pump, maintenance of canals etc.)

Yes ☐ No ☐

3.17. If yes, how much do you pay monthly?.................................

3.18. Have you always been able to pay this fee?

Yes ☐ No ☐

3.19. If no, do you still access the water?

Yes ☐ No ☐

3.20. How many times per week do you have access to water?...................days

3.21. How do you know when your crops need to be irrigated?

irrigate when it's my turn	when the soil is dry	when crops are stressed

3.22. Have you ever had a shortage of water?

Yes ☐ No ☐

If yes, how severe was the problem?

Mild	Moderate	Severe

3.23. When was this problem of water shortage last experienced?

currently	days ago	weeks ago	months ago

PART 4: IRRIGATION SCHEME

4.1. Are you a member of any irrigation scheme?

Yes ☐ No ☐

4.2. If yes, mention the name of the irrigation scheme…………………………………………………….

4.3. How long have you been a member of the irrigation scheme? ……………………… years

4.4. Which type of irrigation system do you use in the scheme?

Sprinkler	Drip irrigation	Furrow irrigation	Centre pivot	Other (specify)

4.5. Have you adopted any of the land or soil conservation practices? Yes/No

4.6. Are you aware of RWH for your produce? Yes/No

4.7. If yes, are you harvesting rainwater for irrigation? Yes/No

4.8. Mention all the challenges you are facing regarding irrigation practices on your farm.

<u>PART 5: HOUSEHOLD FOOD SECURITY STATUS</u>

5.1. Taking all means into consideration, how would you describe your household food consumption in the last 12 months (*Please tick the correct option*)

Food consumptions	**Tick**	**Food consumption**	**Tick**
Food shortages for most of the months		No food shortages	
Occasional food shortages		No surplus	
Food surplus			

5.2.

Answer the following questions using the answers below. 1=Never 2=Rarely= Once or twice in the past month	

3=Sometimes= Three to ten times in the past month 4=Often= More than ten times in the past four weeks 5=Always= All the time **In the past month, did you:**	
Worry that your household would not have enough food?	
Or any of your household members experience not eating the kinds of foods you preferred because of a lack of resources?	
Or any of your household member (s) have to eat a limited variety of foods due to a lack of resources?	
Or any of your household member(s) have to eat some foods that you did not want to eat because of a lack of resources?	
Or any of your household member(s) have to eat less than you felt because there was not enough food?	
Or any of your household member(s) have to eat fewer meals in a day because there was not enough food?	
Experience not having any food of any kind to eat in your household because of a lack of resources to get food?	
Or any household member(s) go to sleep at night hungry because there was not enough food?	
Or any of your household member(s) go a whole day and night without eating anything because there was not enough food?	

PART 6: INSTITUTIONAL FACTORS (markets, extension, organization, finance)

A) **MARKETS**

6.1. Do you have market access? Yes/No

6.2. If yes, do you participate in the market? Yes/No

6.3. How difficult is it for you to look for buyers?

Easy		Fair	Difficult

6.4. When do you start looking for buyers? (*Please tick the correct option*)

Before production	Two weeks before harvesting	Once produce is ready for market

6.5. Where do you sell your produce, and how far is that market?
(*Please tick the correct option*)

Market	Tick	Distance (in km)	Market	Tick	Distance (in km)
Sell at the farm			Sell to neighbours		
Sell by the roadside			Sell to local supermarkets		
Sell to large retailers (i.e. Spar, etc.)			Other (please specify)		

6.6. Do you have regular customers? Yes ☐ No ☐

6.7. Who are your current customers**?** (*Please tick the correct option*)

Friends/neighbours	Hawkers	Teachers	Pensioners	Government Institutions	Spaza shop X

6.8. If there are other possible markets, please mention them below.

6.9. Do you have any contractual agreements (formal or informal)? Give details

----

6.10. How is your produce moved to the marketing point?
(*Please tick the correct option)*

	TYPE OF TRANSPORT					
	Truck	**Bakkie**	**Bus**	**Other (Specify)**	**Distance to market**	**Cost of a single trip to the market (R)**
Own transport						
Hired vehicle						
Public transport						
Buyers transport						
Other (please specify)						

6.11. Is there any produce you could not sell in the past? Yes ☐ No ☐

6.12. If yes, please name the product and the reason for not being able to sell it.
(*Fill the table below*)

Product	Reason
1.	
2.	
3.	
4.	

6.13. What happens to the unsold produce? (*Please tick the correct option*)

Eat with family	Give friends and neighbours	Donate	Loose to spoilage	Sell at low prices	Keep it and sell it later	Process

6.14. Before selling your produce, what value-adding activities do you perform?
(*Please tick the correct option*)

None	Washing	Packaging	Processing	Other(please specify)

6.15. Is there any agro-processing activities that you perform from your produce? Yes/No

6.16. If yes, mention all……………………………………………………………………

6.17. Do you have any access to farming information? Yes/No

6.18. If yes, what or who are your sources of information? (*Please tick the correct option*)

Sources	Type of information provided			
	Prices	Market opportunities	Production	Other(Please specify)
Extension officer				
Media				
Friends				
Co-farmers				
Buyers				
Other				

6.19. How many times a month does the extension officers visit your farm? ....

6.20. How do you want the information to be delivered?
(*Please tick the correct option*)

Post		Telephone		Cell phone SMS	
Internet		Tribal meeting		Extension officers	
Farmer group		Other(please specify)			

PROBLEMS OF MARKETING

6.21. What are the major problems in marketing the produce? (*Please tick the correct option*)

Transport		Lack of packaging house		Market identification	
Financial		Other (please specify)			

6.22. Suggest ways in which such problems can be addressed

6.23. What problem do you experience in moving your produce? (*Please tick the correct option*)

The small size of the transport	Lack of transport	High transport cost	Other(please specify)

B) FINANCIAL SERVICES

Do you have access to credit? Yes/No

6.24. Did you use any credit or loan facility in the past 12 months?

Yes ☐ No ☐

6.25. If yes, what was the main source of credit/loan?

Main source of credit/ loan	Tick	Main source of credit/loan	Tick
Relative or friend		Input supplier	
Money lender		Financial institution (Specify the name of financial institution)	
Savings club(stokvel)		Output buyer	
Other(please specify)			

6.26. What was the purpose of the loan/credit?

Family emergency	Agricultural purposes	Other(please specify)

6.27. Were you able to pay back the loan/credit in time?

Yes ☐ No ☐

6.28. Did you receive funding or any other sources of credit support from the government in the past 12 months?

Yes ☐ No ☐

6.29. If yes, in 6.28, how often?

Sometimes ☐ Always ☐

C) EXTENSION SERVICES

6.30. Did you have any contact with an extension officer(s) in the past 12 months?

Yes ☐ No ☐

6.31. If yes, how often did you contact extension officers?

Once a week	Twice a week	Once a fortnight	Once a month	Once in 6 months

6.32. If yes, at 6.30, did you invite the extension officers?

Yes ☐ No ☐

6.33. Are the extension officers from:

Government/parastatal	Non-governmental organisation (NGO)?	Private company?

6.34. What services are provided by the extension officer? (*Please tick the correct option*)

Type of service	Tick	Type of service	Tick
Advice on production		Advice on management	
Advice on processing		Advice on funding	
Other(please specify)			

6.35. List the problems that you have encountered with the extension officer in your community.

6.36. How would you rate the extension services in your area? (*Please tick the correct option*)

Excellent	Good	Average	Poor

6.37. Did you receive any free inputs in the past 12 months?

Yes ☐ No ☐

6.38. If yes, what was the source?

Government X	Non-governmental organisation (NGO)	Private company

6.39. If yes, in 6.37, please specify the type of inputs received and their quantities

....

....

6.40.

Main source of farming information	Tick	Main source of farming information	Tick
None		Internet	
Radio/Television		Newspaper	
Extension officer		Other farmers	
Cell phone/SMS		Other(please specify)	

6.41. Do you understand the information disseminated by the main source in 6.40

Not at all	Somewhat	Absolutely

PART 7: ENTREPRENEURSHIP SKILLS

7.1. Do you consider farming as a business? Yes ☐ No ☐

7.2. Do you need any form of training to improve your skills? Yes ☐ No ☐

7.3. If yes, what specific training is required? (*Please tick the correct option)*

Skill	Yes	No	Reason
Crop production			TO BROADEN UP KNOWLEDGE
Record keeping			
Marketing			
Value-adding			
Other(please specify)			

7.4. If no, have you received any type of training related to the agricultural field that is in? (*Please tick the correct option*)

Year	Type of training	Institution

7.5. How often do you attend or participate in the following educational activities?

(Please tick the correct option)

Type of educational activities	Never	Once a month	Once in three months	Once in six months	Other (please specify)
Farmers/information day					
Agricultural workshops					
Agricultural short courses					
Educational tours					

7.6. How do you rate your farming knowledge? (*Please tick the correct option)*

Type of knowledge	Rate					
Farmer knowledge	Poor		Average		Good	
Workers knowledge	Poor		Average		Good	

How the knowledge was acquired	Education		Training		Experience	

7.7. Do you do skills transfer to those working on your farm, and how?-------------------------------

7.8. Please indicate by ticking if you keep any of the following farming records**.**

Type of record	Tick	Type of record	Tick	Type of record	Tick
Financial records		Production records		Labour records	
Other(please specify)					

7.9. What missing resources would you consider useful in improving your enterprises? (*Please tick the correct option)*

Production inputs		Infrastructure		Pack-house	
Technical information		Technical equipment		Labour	
Other(please specify)					

7.10. Do you see yourself as a potential commercial farmer one day? Yes ☐ No ☐

7.11. If you disagree, what are the factors holding you back?
7.12. If you agree, how do you plan on expanding your farming operations?

7.13. Would you consider forming a partnership with other farmers/entrepreneurs?

7.14. What are the main challenges that you face in running your farming business

Challenges	Tick
Inputs	
Drought	
Production costs	
Labour	
Disasters	
Management skills	
Market availability and access	
Transport	
Other (please specify	

Skills and Training.

8.1. Have you ever been trained *1=Yes 0=No*

8.2. Do you currently need training in any of these areas *1=Yes 0=No*

General crop/vegetable production	

Land preparation	
Fertiliser application	
Herbicide application	
General irrigation practices	
Irrigation scheduling and water management	
Agricultural commodity marketing	
Packaging of fresh produce	
Processing of farm produce	
Pricing of products, including negotiation of prices	
Business planning	
Budgeting/ Bookkeeping	
If other (please specify)	

Thank you for your participation