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Exploring the Barriers to the Adoption of Climate-Smart Irrigation Technologies for Sustainable Crop Productivity by Smallholder Farmers: Evidence from South Africa

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Abstract: Climate change continues to impact the livelihoods of smallholder farmers due to low adaptive capacity. In South Africa, the challenge is exacerbated by water scarcity and shortened crop-growing seasons. Climate-smart irrigation innovative technologies (CSIT) enhance smallholder farmers' resilience to climate change. However, there is still a limited level of effective adoption and usage of these technologies in smallholder communities. This study investigated the barriers affecting the adoption of CSIT in rural areas of the Vhembe and Capricorn districts in Limpopo Province, South Africa. We explored the farmers' socioeconomic factors extracted from farmers' perceptions of CSIT-specific attributes. A multi-stage randomized sampling technique was used to select 100 smallholder farmers (SHF). Data analyzed by descriptive statistics such as percentages and frequency distribution are presented in graphs and tables. According to the findings, insufficient communication channels, a lack of financial availability, unstable land tenure systems, and insufficient training are the main obstacles to implementing CSIT. There is a need for policy and decision-makers to improve the communication channels for disseminating agro-meteorological information to the intended beneficiaries.

Keywords: agriculture; socio-economic constraints; food security; resilience and adaptation; sustainable development

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1. Introduction

The agricultural sector in South Africa is crucial since it generates about 3% of the nation's GDP, 40% of export revenue, and 4.6% of the labour force. It also provides the food and household income vulnerable populations need to meet their necessities [1,2]. Despite the sector's contribution to economic growth and poverty reduction, agricultural productivity has failed to be at par with population growth. The main reason is poor soil fertility, resulting from continuous cropping without replenishing the nutrients removed from harvested produce [3,4]. Prolonged dry spells, high levels of rainfall variability, and extreme weather-related hazards such as floods, droughts, hailstorms, and frosts are all contributing factors that make the situation worse [5,6]. In South Africa, the occurrence of these risks has been seen as a shift toward delayed onset and early cessation of rainfall, which has led to a shorter growing season and an increase in the frequency of mid-season dry spells, droughts, and floods, all of which are anticipated to become more frequent and more intense due to predicted climate change [6,7]. The agricultural industry in the nation is dualistic, with 4 million under-resourced smallholder farmers (SHF) cultivating 13% of the country's agricultural land and a limited number of well-resourced commercial farmers producing 95% of all agricultural output on 87% of all agricultural land [8]. The existing literature indicates that, although climate variability will bring about substantial welfare losses to all categories of farmers, SHF is among the most vulnerable to changing climate conditions because their heavy dependence on rain-fed agriculture makes them more prone to periods of water scarcity which will significantly affect crop production [9]. Potentially undermining progress towards poverty alleviation, food security, and sustainable development [10–12]. As a result, the smallholder sector only sometimes reaches levels above subsistence farming.

Developing adaptation and enhancing resilience strategies are often the most appropriate and responsive means for SHF to reduce risk and vulnerability to climate change [13]. According to Teshome et al. [14] and Shikwambana and Malaza [15], SHF has always responded to climate variability through traditional adaptation strategies such as crop diversification, incorporating crop residues into the soil, changing planting dates and water conservation practices. In the context of climate variability, all these adaptation strategies play an essential role because they are an important integral component of climate-smart agriculture (CSA), which have been widely promoted to strengthen livelihoods and food security, especially for smallholders, by improving the management and use of natural resources and adopting appropriate methods and technologies for producing, processing, and marketing agricultural goods [16].

However, South Africa is the 30th most arid country in the world, making it prone to droughts, and the Limpopo Province is one of the provinces most impacted by droughts [8,17]. The importance of water conservation through adopting climate-smart irrigation technologies (CSIT) cannot be overemphasized. CSIT has been defined as good irrigation practice for a given agro-climatic and societal context that takes explicit account of challenges and opportunities that may result directly or indirectly from different facets of climate change [16]. While TNA [17] indicated that CSITs are a complex of interconnected structures and devices, which ensures an optimal water–salt regime in the upper soil layer for high crop yields. These technologies include, among others, rainwater harvesting, contour ridges, terraces, and drip irrigation [18]. According to Batchelor and Schnetzer [16], these technologies aim to increase agricultural productivity and incomes derived from irrigated cropping systems up to and beyond the farm gate without negatively impacting the environment or other water users and uses (in space and time). In addition to the increased crop yields, there are also significant benefits for economic and social development, including reduced fertilizer costs, reduced water transport costs, reduced soil degradation and erosion, growing soil organic matter, improved public health due to reduced fertilizer use and their content in water [17]. However, most of these CSITs are not practiced or adopted by smallholder farmers, especially in the Limpopo Province. Despite the availability of a wide range of CSIT and well-documented effectiveness in coping with climate variability in resource-constrained rural communities, there is increasing evidence that SHF are failing to manage climate variability due to poor adoption of recommended CSIT [7,19]. This continues to be a significant drawback to productivity, sustainability, and resilience-building initiatives. As the impact of CSIT can only be assessed once SHF starts to accept and adopt the technology [5,20]. However, theoretical explanations and empirical evidence indicated that restrictions regarding adopting CSIT by SHF in South Africa are often linked to gender-based barriers, lack of knowledge, and lack of access to farm resources and markets. Against this background, the study aims to add to existing information by evaluating barriers affecting the adoption of CSIT among SHF in the Vhembe and Capricorn districts of the Limpopo Province, South Africa.

2. Materials and Methods

2.1. Description of the Study Areas

The study comprises two districts, Vhembe and Capricorn, in the Limpopo Province of South Africa (Figure 1). The Vhembe district (22.7696° S, 29.9741° E) is located in the northern part of the province and covers a total area of 2,140,708 ha, of which 249,757 ha are considered to be arable land [21,22]. It is subdivided into four municipal areas (Figure 1), namely Makhado, Musina, Thulamela, and Collins Chabane [23]. Being characterized as a semi-arid area, the district receives low erratic rainfall patterns ranging between 246 mm to 681 mm per annum (Table 1), usually resulting in severe droughts [24–26]. In comparison, the mean annual temperature ranges from 9 to 17 °C during winter and 22–37 °C during summer (Table 1).

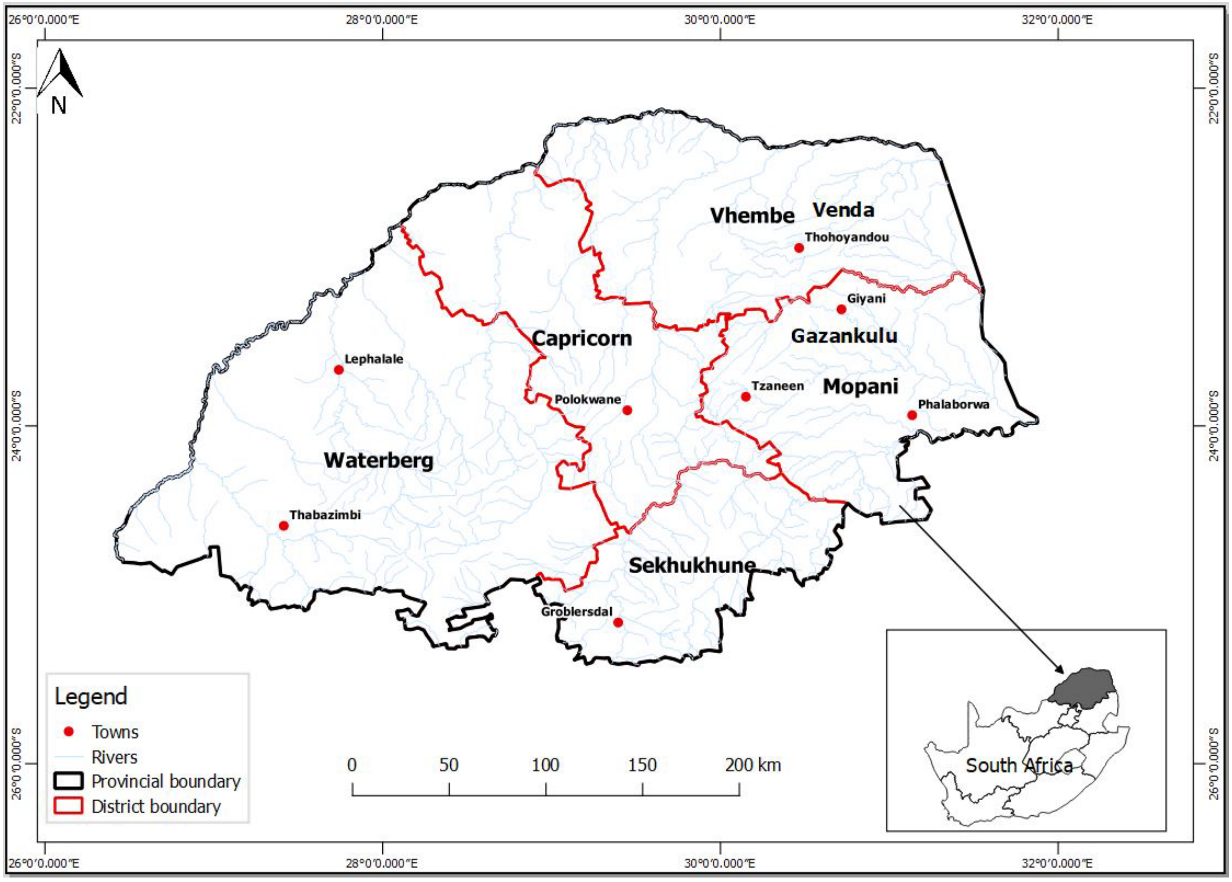

Figure 1. Map indicating the Capricorn and Vhembe districts.

Table 1. Long-term (2010–2020) weather information of the Vhembe and Capricorn district.

District	Month	TX	Tn	RHx	RHn	Rain	ETo
Vhembe	January	29.42	20.13	93.33	57.61	425.37	91.23
	February	29.1	19.84	93.56	57.48	352.36	75.36
	March	30.04	17.3	93.27	46.6	439.85	92.38
	April	28.66	15.48	92.92	46.16	0	73.87
	May	28.01	11.08	91.55	32.75	0.76	74.51
	June	25.71	9.13	90.25	33.65	1.02	60.9
	July	24.24	8.1	88.53	31.68	12.95	68.94
	August	26.7	11.17	88.32	34.35	24.89	70.48
	September	28.67	12.88	85.05	32.25	6.6	89.78
	October	27.65	14.86	87.97	44.22	100.08	81.22
	November	31.43	18.42	85.63	41.35	99.57	97.5
	December	30.13	19.2	91.51	51.31	212.09	98.67

Table 1. *Cont.*

District	Month	TX	Tn	RHx	RHn	Rain	ETo
Capricorn	January	28.32	17.65	94.57	48.37	106.43	129.4
	February	27.46	16.71	97.73	47.93	85.6	103.03
	March	27.4	13.63	97.05	39.86	30.99	115.67
	April	27.29	8.66	94.3	29.02	0.51	107.63
	May	24.35	4.78	92.47	27.43	3.05	91.7
	June	22.08	2.88	90.6	27.2	0.25	76.21
	July	20.4	1.65	87.93	25.3	0	82.42
	August	23.36	5.99	81.88	25.95	50.55	98.27
	September	25.76	9.91	85.28	31.54	58.17	119.8
	October	26.22	12.6	85.46	36.19	26.92	133.3
	November	28.57	15.55	92.2	38.53	177.29	136.47
	December	27.33	16.45	95.86	48.57	115.82	128.03

ETo: Evapotranspiration; Tx = maximum temperature; Tn = minimum temperature; RHx = maximum relative humidity; RHn = Minimum relative humidity.

Vhembe district (Figure 1) covers a predominantly rural geographical area and is home to a population size of 1,294,722 people. It is well known for economic sectors such as mining, community service, finance, and agriculture [21,22]. The agricultural sector contributes 22.8% of Limpopo's GDP [21]. In the Limpopo Province, 136,000 people are employed in the agricultural sector specializing in livestock, fruits, vegetables and tea (Table 2). SHF, located mainly in the former homeland areas, represents 70% of the farming activities in the district [27]. Generally, producing vegetables such as cabbage, black nightshade, chillies, mustard spinach, tomatoes, onions, and pumpkins, with the majority of them being grown under irrigation schemes that use both indigenous (furrow irrigation) and modern irrigation techniques (drip irrigation) [28–30]. Others, however, rely on seasonal rainfall to grow leguminous crops, including groundnuts, Bambara nuts, and cowpeas, as well as staple maize crops [27,28]. Despite agriculture being the key contributor to employment and livelihoods in the district, SHF farming activities are characterized by low production levels [12,27].

Capricorn district (23.6123° S, 29.2321° E), which is located at the centre of the Limpopo Province (Figure 1), is considered the economic development core because it is home to the provincial capital city of Polokwane [31,32]. Luvhengo [33] also indicated that the evaluation of the agricultural gross geographical product (AGGP) of the Limpopo Province revealed that the Capricorn district ranked fourth, contributing about 15% to the total AGGP. The district covers a total area of 185, 222.27 ha, 12% of the Limpopo Province's total population of 1,409,354 [32,34]. The Capricorn district is divided into four local municipalities: Polokwane, Blouberg, Molemole, and Lepelle-Nkumpi [34]. The climate is semi-arid, characterized by wet and hot summers and cool and dry winter seasons [30]. The highest temperature of 25 °C is often experienced in January, and the lowest average of 10 °C in June [33].

In comparison, the mean annual rainfall ranges from 300 mm in the northern half of the district to 1000 mm in the southern half [30]. With the highest rainfall experienced between January to February, the likelihood of flood occurrence is at its highest [31]. Besides being home to one of the largest citrus estates in the country (Zebediela Citrus Estate), potatoes are also the most produced vegetables in the Capricorn district, followed by tomatoes [34]. Of the total area of Limpopo Province, the two districts contribute significantly to agricultural production and some of the activities are aligned with commercial products [35–38]. Although SHF, which has a land tenure of only about 2 ha, is dominant in the district, they face various challenges. These include limited access to markets, lack of collateral to access financial support from banks, lack of storage facilities, ageing equipment, poor roads, vandalism, extreme weather events and poor access to agro-meteorological information [31].

Table 2. Description of economic distributions in Limpopo Province.

	Limpopo Province	Items	Reference
1	Total area	125,755 km^2	[35]
2	Area of agricultural land	140,000 ha	[36]
3	Number of people employed in the agricultural sector	136,000	[37]
4	Agricultural specialization	Livestock, fruits, vegetables, cereals, and tea	[38]
5	Commercial products	Mining (15–20%), trade (17%), financial and business services (10–12%), and agriculture (9.7%)	[36]

The pH and concentrations of Na, K, Mg, Ca, and P are presented in Table 3 for the Capricorn and Vhembe districts. In comparison to the two districts, the Capricorn district appeared to have intermediate to high levels of resistance, P, K, and Na (Table 3). The soil from the Vhembe district was primarily alkaline, with an average pH of 8.7. As shown in Table 3, the low availability of nutrients, especially micronutrients, is a significant concern in alkaline soils.

Table 3. Description of soil nutrients of the two districts (Capricorn and Vhembe).

Soil Nutrients		Capricorn District	Vhembe District
Macronutrients (mg/kg)	P	66	9.5
	K	187	129
	Ca	820	1139
	Mg	210	478
	Na	275	86
	pH (H_2O)	6.5	8.7

2.2. Sampling Technique and Data Collection

A multistage sampling approach was used to conduct the survey. The first stage involved the purposive selection of two districts (Vhembe and Capricorn districts) out of five districts in the Limpopo Province. These districts were selected as the areas of study because they have limited research information regarding the adaptation of SHF to the effects of climate change, and they are confronted with various socio-economic barriers in producing and marketing their products [28,39]. According to Musetha [18], the Vhembe district is among the rural districts where the farmers face challenges that include a lack of climate change awareness and adaptation, high poverty and low crop production. In the second stage, within each district, four local municipalities were further selected purposively, Makhado, Musina, Thulamela, and Collins Chabane local municipalities under the Vhembe district. Polokwane, Blouberg, Molemole and Lepelle-Nkumpi were selected in the Capricorn district. These local municipalities were selected because a significant proportion of land is used for agricultural purposes. These municipalities are predominantly smallholder farming areas, albeit the negative climate change experiences include droughts, heatwaves, and flooding.

Annual rainfall in the selected districts is between 300 mm and 400 mm [12,31]. The final stage involved selecting the population who participated in this study, comprised SHF residing in the two districts. This study used random sampling to select 100 SHF who covered different agro-ecological zones [40]. Fifty participants (10 within each local municipality) were targeted from each district. The list of SHF who met the relevance criteria was provided by the respective local offices of the Limpopo Department of Agriculture and Rural Development (LDARD) in each local district. The sampling technique was used to assess uniformity and homogeneous characteristics and meet the study's objectives while adhering to the statistical specifications for accuracy and representatively.

The primary data for the study were collected through a structured questionnaire in September 2020. The questionnaire, which consisted of open- and closed-ended questions, was subdivided into demographics, farm characteristics, household food security, institutional factors, and entrepreneurship skills (Table 4). The participants' awareness of CSIT was assessed by asking whether they have heard of technologies such as drip irrigation and conservation agriculture methods such as rainwater harvesting commonly used to adapt to climate change impacts. Trained enumerators who not only spoke the local languages, i.e., Sepedi (Capricorn district) and TshiVenda (Vhembe district), but also had experience and knowledge of the smallholder farming systems within the study areas, assisted with administering the questionnaire. In addition, to combat the spread of COVID-19 during the field survey, the following measures were designed: Before leaving their home, everyone was required to assess themselves for COVID-19-related symptoms; upon arrival, all participants were required to undergo a temperature check, and if the temperature was 37.4 °C or higher that individual would be sent back home. It was also mandatory for everyone to be provided with adequate personal protective equipment (PPE) that include face masks, gloves, and ≥70% alcohol hand sanitizer. As a precaution to abide by the rules, participants and enumerators were obliged to keep a 2 m distance [40].

Table 4. Inclusion and exclusion criteria for survey selection.

Inclusion Criteria	Exclusion Criteria
Smallholder farmer	Commercial farmer
Vegetable production	Field crop production
High dependency on irrigation	Rain-fed agriculture
Land size ranging between 1 to 5 ha	Land size of more than 5 ha

2.3. Model Specification

The link between the response variable (dependent variable), which has two or more categories, and one or more explanatory variables (independent variables) on a categorical or interval scale can be predicted using the statistical analysis technique known as logit regression model [41]. This study used the model to explore the CSIT adoption barriers based on the explanatory variables that may affect SHF adoption decisions (Table 5). Due to the fact that the dependent variable is a dummy variable (dummy variable, Y = 1; Y = 0), the model was expressed as follows:

$$\mathrm{Ln}\left[\frac{\mathrm{p}(\mathrm{Y}=1)}{\mathrm{P}(\mathrm{Y}=0)}\right] = \beta_0 + \beta_{1\times1} + \beta_{2\times2} + \beta_{3\times3} + \ldots\ \beta_{10\times10} \quad (1)$$

Of which:
P(Y = 1) = P0: The probability of SHF not being affected by adoption barriers.
P(Y = 0) = 1 − P0: The probability of SHF being affected by adoption barriers.
Xi: Independent variables (i: from 1 to 10); Ln: Log of base e (e = 2714).

Table 5. Description of variables in the multinomial logistic regression model.

Variable	Description	Unit of Measurement
Age	Age of a farmer	Years
Education	Level of farmers' education	Years
Farming experience	Number of years spent in farming	Years
Member of the irrigation scheme	Whether the farmer belongs to an agricultural-related group or association	1 = yes, 0 = no
Infrastructure	Access to farming infrastructure	1 = yes, 0 = no
Production costs	Production expenses of adopting CSIT	1 = yes, 0 = no
High maintenance	High maintenance of CSIT	1 = yes, 0 = no
Distance	Distance to the market	Km

2.4. Data Analysis

Software for Statistics and Data Science version 15 (STATA 15) was employed to analyse the data. Descriptive statistics such as frequency distribution and percentages were presented in graphs and tables, while the logit model results were presented in a table.

3. Results and Discussion

3.1. Adoption Status of CSIT in the Study Areas

Adoption has been identified as the decision to use a new technology or practice by an individual, household, or community [42]. However, introducing new agricultural technologies to farmers can only be helpful if they adopt [43]. Table 6 indicated that in the Vhembe district, the adoption of CSIT was low because only 24% of participants adopted the technology. Whereas in the Capricorn district, 68% of the participants were recorded to have adopted the technologies. The variation in the adoption status observed among the adopters and non-adopters in the two districts can be explained by the fact that a farmer's decision to adopt or reject the technology is a dynamic process. As it involves changes in farmers' perceptions and attitudes, the progression in the acquisition of better information and farmers' ability and skill improvement in applying new technology [44]. 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, socioeconomic factors, and other institutional constraints [45].

Table 6. Adoption status of CSIT in the study area.

	Vhembe		Capricorn	
Technology Adoption Status	***n***	**%**	***n***	**%**
Adopters	12	24	34	68
Non-adopters	38	76	16	32
Total	50	100	50	100

n = number of participants.

3.2. Communication Channels Used for Awareness Creation

Awareness is the first step to adopting improved agricultural technologies, particularly those not yet widely known [46]. As a new technology often carries risks and opportunities, farmers are more likely to try out a new technology that is less risky and with higher expected benefits relative to the prevailing technology [47,48]. The results in Table 7 reveal that by the time of the survey, 97.83% of adopters were aware of these technologies. However, they did not classify them as climate-smart but rather as a form of farming practice, and only 2.17% of the intended beneficiaries lacked awareness. In the case of non-adopters, it was the opposite, as only 16.67% had some basic knowledge of these technologies compared to the 83.33% who were recorded to have insufficient or no knowledge of CSIT. According to Popoola et al. [49], low awareness among SHF often results from access to information primarily dependent on the infrastructure required for its dissemination is usually unevenly distributed within regions, thus resulting in some farming communities being more knowledgeable than others. Moreover, a majority of the farmers are unable to answer the critical questions of what?" "how?" and "why?" in the knowledge phase [50].

Therefore, results obtained regarding the level of awareness among adopters and non-adopters highlight the importance of participants having access to accurate information on agricultural technologies to reduce uncertainty and make rational decisions [51]. However, the successful diffusion of information on any technology often depends upon the types of communication available to the participants [52,53]. The results indicated that extension officers, as a communication channel, were reported to be in use by 72% of adopters and 28% of non-adopters (Figure 2). These findings indicate that extension officers are more accessible to adopters of CSIT. This is often a result of the frequent contact that extension officers have with the farmers, which creates more awareness and reduces the difficulty in the adoption process. These findings align with Udimal et al. [54], who reported that technology adoption among farmers is higher when extension services are made available.

Table 7. Awareness status of CSIT in the study areas.

Level of Awareness	Adoption Status			
	Adopters		Non-Adopters	
	N	%	*n*	%
Yes	45	97.83	9	16.67
No	1	2.17	45	83.33
Total	46	100	54	100

n = number of participants.

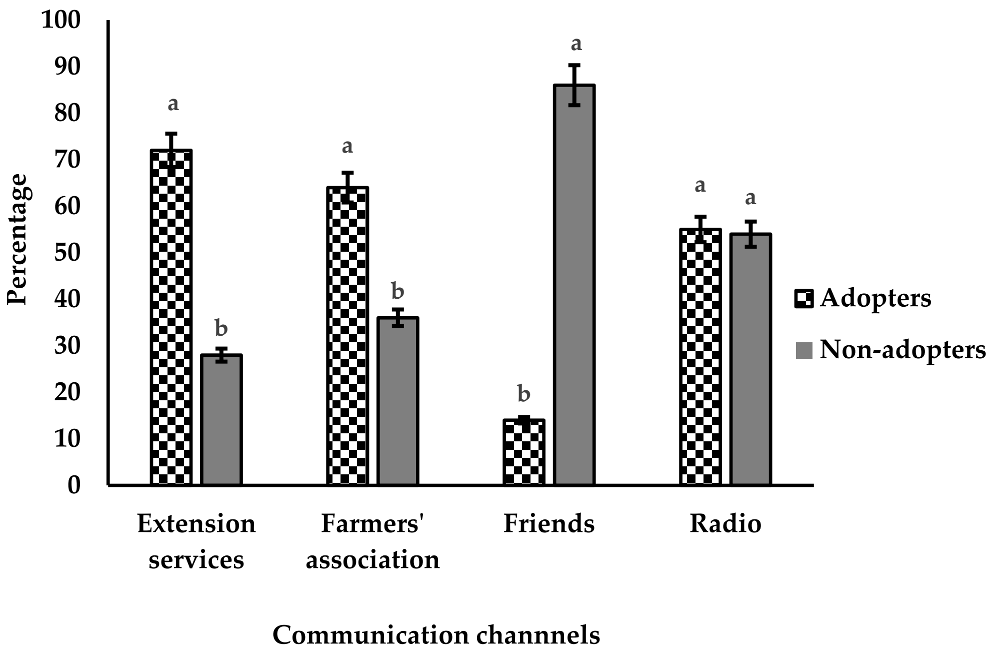

Figure 2. Communication channels available to the SHF.

In contrast, non-adopters had limited access to extension workers, often in relation to an inadequate number of extension officers and insufficient funds for supporting farmer fields, schools and farmer demonstration plots that constrain the flow of information reaching farmers [51,55]. Thus, it prevents farmers from asking questions and seeking clarification on the challenges they experience from adopting the newly introduced technology [56]. In cases where the target beneficiaries are excluded from the extension process, farmers may take the initiative to learn from other sources [56,57].

Findings revealed that 64% of adopters and 36% of non-adopters resorted to farmer associations to receive information on agricultural technologies. This implies that most adopters in the study area belonged to a farmers' association, which not only enables them to share information during informal open discussions at agricultural fairs, with workshops organized by farmers and associations, but also to enjoy the benefits accrued to co-operative societies through a pooling of resources for a better expansion and effective management of resources and farms [58,59]. In contrast, other sources of information included friends, which were used by 14% of adopters and 86% of non-adopters. A large percentage of adopters' dependence on such interpersonal communication results from the fact that it assists in breaking the barrier of formal relationships, generating warmth, and creating harmony necessary for socio-economic development [60].

Furthermore, only 55% of adopters and 45% of non-adopters have been reported to rely on radio, respectively. The popularity of radio as an effective channel for communicating information is often linked to its ability to reach illiterate farmers with content related to agricultural production in understandable language [57]. It can be concluded that using a single channel cannot be effective and best for all situations in the communication process. Therefore, using a combination of channels will help appeal to different human senses, thus aiding in the easy understanding of messages.

3.3. Sources of Funding for Implementing CSIT

Credit availability, either in cash or non-monetary form from government or private institutions, is an essential institutional service for assisting poor farmers with input purchases and ultimately adopting new technologies [61,62]. The existing literature has also ranked SHF as poor or having no access to formal credit among the first three challenges after access to land and markets, constraining the development of SHF [63]. Due to that, a farmer's decision on whether to adopt is even more challenging when the new technology involves a high initial investment [64]. Table 8 shows that most adopters (86.96%) had no access to credit, and a smaller proportion (13.06%) had access to credit. Similarly, access to credit through formal institutions is non-existent for (98.15%) of the non-adopters, and 1.85% of the adopters had access to credit. The extremely low access to credit 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 [65,66]. Some problems may also be related to the repayment of the loans, particularly after a poor harvest [64]. Thus, some participants either avoid formal credit or borrow money from friends, family, and informal lenders to meet their financial obligations [67].

Table 8. Sources of funding used to support SHF in adopting CSIT.

Support	**Adopters**		**Non-Adopters**	
Formal Credit	***n***	**%**	***N***	**%**
Yes	6	13.04	1	1.85
No	40	86.96	53	98.15
Total	46	100	54	100
		Own support		
Yes	12	26.08	11	20.37
No	34	73.92	43	79.08
Total	46	100	54	100
		Government Funding		
Yes	31	67.39	43	20.37
No	15	32.61	11	79.63
Total	46	100	54	100

n = number of participants.

The findings also indicated that in the study areas, it was found that 73.92% of the adopters were often hesitant to use their own money for investing in agricultural technologies, and 26.08% of the adopters were willing to invest their funds. There was also no difference among the non-adopters because about 79.63% had no access to sufficient off-farm income, which they could use for technology investment, and 20.37% had financial willpower. This shows that a lack of adequate off-farm income can lead to participants not adopting the technology. This is probably because most depend on government support such as social grants, child grants, pensions, old age grants and disability grants as a supplementary source of income. Unfortunately, these types of income will not be able to cover the implementation cost of CSIT, such as drip irrigation which can be very expensive, particularly at the initial stage. For instance, Kibirige [68] indicated that implementation of a drip irrigation system had been estimated at 530.43 to 1532.35 USD (9396 to 27,144 ZAR at an exchange rate of 1 USD = 17.7432 ZAR) per ha, including the annual costs incurred by the farmer to pay for water, operation, and maintenance. Other CSITs, such as mulching and rainwater harvest, are less expensive. These results corroborate with Anuga et al. [69], who reported that high costs associated with CSA technologies could also serve as a hindrance to farmers, primarily SHF associated mainly with low-income levels.

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 adopting innovations. In this study, 67.39% of the adopters pointed out that they have received funding in the form of inputs for the past 12 months, and 32.61% of the adopters indicated that they received no funding from the government. On the other hand, about 20.37% of the non-adopters had access to funding, and 79.63% of the non-adopters did not have access to funding. According to Baloyi [28], partial funding is often regarded as a fruitless expenditure, particularly for poor SHF, whose financial resources do not have to complement the on-farm infrastructure provided by the government. This indicates that SHF should be encouraged to form farmer groups/associations as these may enable them to save and borrow money for investment into improved CSIT through the provision of credit [70]. Furthermore, communication channels should also connect farmers with irrigation officers to correctly design systems before purchasing irrigation equipment [71].

3.4. Land Tenure Arrangements

The land tenure system has also been identified as one of the most critical factors hindering SHF adoption of CSIT. To understand why most participants had no access to credit and the low adoption rate of CSIT, it was necessary to examine the land tenure arrangements of the study areas. As indicated in Figure 3 the study found that 26% of adopters acquired land through allocation by the chief, 22% bought the land, and 52% inherited the land. These findings show that most SHF had access to land through inheritance under a secure land tenure system, which increases the likelihood of adopting CSIT. This is because land tenure security enables SHF to use agricultural land as collateral for larger loans to cover increased fixed and variable production costs associated with adopting new technology [44]. Thus, reducing some level of risk and uncertainty for the SHF, especially the extent to which farmers are prepared to invest in improvements in production, sustainable management, and adoption of new technologies and promising innovations [44,72].

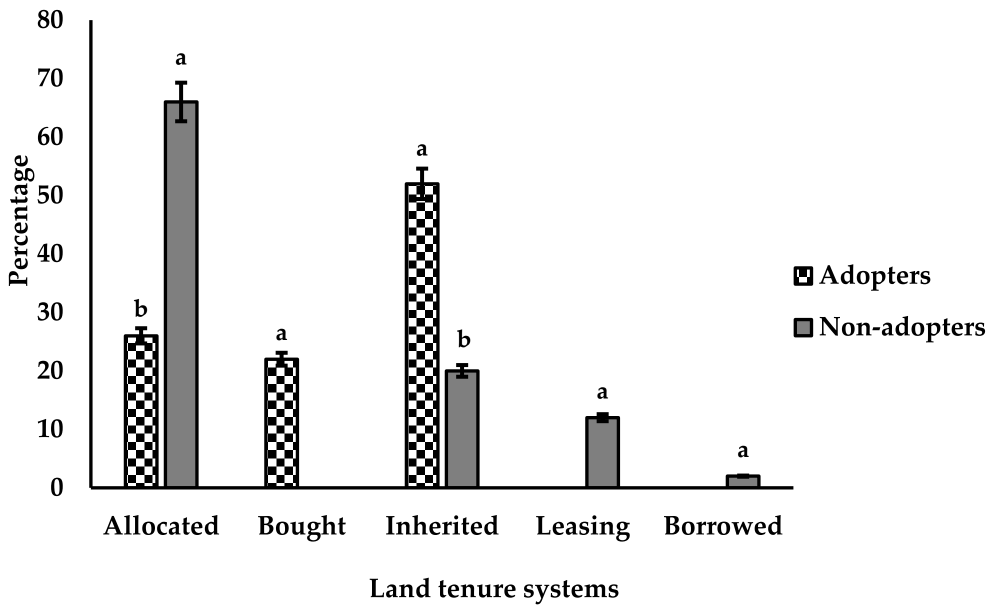

Figure 3. Land tenure systems of SHF.

While 66% of non-adopters had access to land through allocation by the chief, 20% inherited the land, 12% were under a lease agreement, and 2% borrowed land from a friend/neighbour. This postulates that most non-adopters under insecure land rights diminish farmers' incentive to invest in the land since they must bear the uncertainty of whether they will be able to recap their investment [73]. Due to that, 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 but if the allocated land is not cultivated for a certain period, it may be returned to the community [24,74,75]. In addition, there is still gender disparity in land management under this tenure [76]. This was observed in the North West Province, where women tend to have smaller landholdings that are less fertile, and these are often accessed through their male relatives [77]. This discourages farmers from investing and making sustainable improvements vital for agricultural productivity due to the lack of transparency and accountability in managing customary lands [63,78]. These findings reveal that there is still a need to implement the right institutions to ensure compensation for labour and other long-term investments on the land for farmers, particularly those under customary and rental tenure systems. Moreover, government officials should look at developing a policy to address gender gaps because women are still vulnerable and insecure even in these assumed women-friendly customary systems.

3.5. Access to Training

Agricultural training is another effective channel in which farmers are equipped with the information and technical know-how required to adopt relevant technologies [79,80]. From the survey, it has been found that 83% of the adopters and 74% of the non-adopters had undergone training (Figure 4). However, access to training does not necessarily mean that the SHF will adopt the technology because the number of times the farmer has been trained in technology significantly influences agricultural innovation adoption [53]. In some cases, extension agents who are often responsible for carrying out the training are in a position of knowledge and experience similar to that of farmers in CSIT, such as micro-irrigation [81].

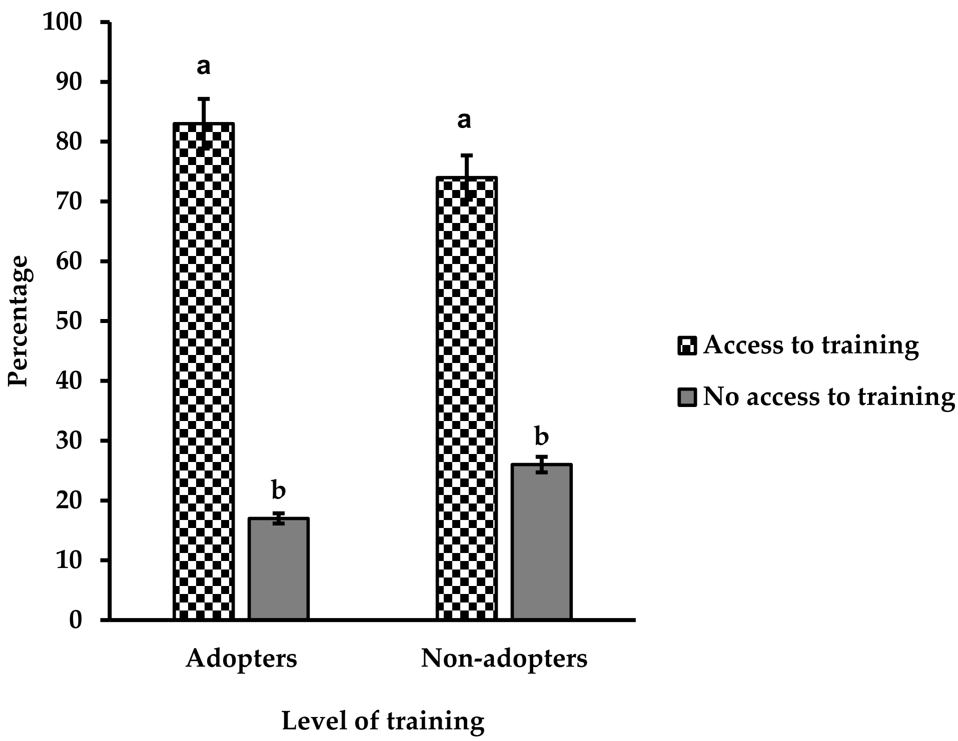

Figure 4. Comparison of SHF access to agricultural training.

While 17% of the adopters and 26% of the non-adopters 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. Similarly, 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. In contrast, others do not even know where such training is offered in the study area. These findings are corroborated by Njenga et al. [57], who ascribed the low number of trained farmers to a decline in the availability of service providers and trainers, such as extension agents, and an increase in the price of training. Therefore, the key lesson here is that all stakeholders should participate as learners alongside farmers in all hands-on training and not just as controllers who introduce the technologies to farmers.

3.6. Types of CSIT Training Programmes Attended by SHF

Training that is received either theoretical (textbook, oral presentation) or applied (demonstration, on-farm trial, farmer field day) is considered an essential tool used to assist farmers in overcoming complexities that are associated with the use of the technology and accurately assessing its advantages and ability to meet the farmers' needs [79]. Tshwene [81] 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 in the study area. The findings presented in Table 9 indicate that 69.57% of the adopters and 51.85% of the non-adopters attended a farmers field day, 80.43% of the adopters and 27.78% of the non-adopters acquired their skills through the attendance of a workshop/seminars. In contrast, the attendance of agricultural short courses was fairly low because only 6.25% of adopters and 7.41% of non-adopters 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. In contrast, informal training programmes such as farmers field days are more effective because participants can observe the use of agricultural technologies through practical demonstrations.

Table 9. Types of agricultural training programmes undertaken by SHF.

Training Programme	**Adopters**		**Non-Adopters**	
	n	**%**	***N***	**%**
Farmers field day				
Yes	32	69.57	28	51.85
No	14	30.43	26	48.15
Total	46	100	54	100
Workshop/seminar				
Yes	37	80.43	15	27.78
No	9	19.57	39	72.22
Total	46	100	54	100
Agricultural short courses				
Yes	3	6.52	4	7.41
No	43	93.48	50	92.59
Total	46	100	54	100

n = number of participants.

Despite the attendance of these different agricultural programmes, it has been revealed that some of the participants' training programmes 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 farming skills: production, marketing, and business management. Figure 5 shows that 70% of adopters and 76% of non-adopters said they still need more training in climate-smart crop production techniques such as irrigation frequency and scheduling, determining intra- and inter-row spacing, applying eco-friendly herbicides and fungicides, and fertilizer application. These techniques are crucial because improper use of them could harm yield, the environment and, consequently, the livelihood of nearby people. Such training requires interpersonal channels, such as on-farm demonstrations, which enhance interaction and feedback between a source and receiver [82]. For instance, du Plessis et al. [79] mentioned that demonstrations play an essential role in assisting farmers in avoiding damage to the components of the drip system, such as puncturing of pipe and, in cases where the laterals need to be moved from time to time, farmers need to be trained on how to execute this task in a way that prevents dirt from entering the components. Although both groups have been recorded to face marketing challenges, there seems to be no training provided in this regard among the non-adopters, as 70% compared to the 17% of the adopters indicated that to obtain 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. According to Plantinga [83], the relationship between market access and technology adoption can work both ways. Firstly, to increase SHF participation in markets, they need to increase their production by adopting new agricultural technologies such as CSIT. Due to this, a farmer's income and motivation to produce may improve when they have better access to markets with better prices [82]. In contrast, 80% of adopters and 24% of non-adopters noted that training in the proper application of business skills, such as financial management, would help them to be managers of their finances and support themselves in adopting CSIT.

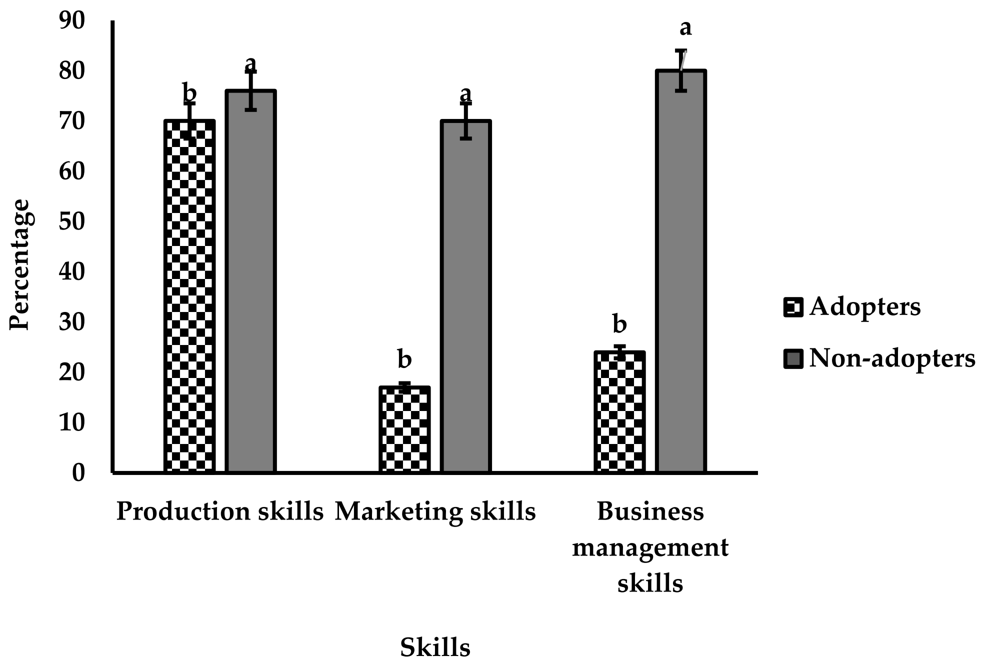

Figure 5. Assessment of SHF skills in agricultural production.

4. Logit Regression Results

The findings of the Logit regression results are presented in Table 10, which shows that the chi-square probability (Prob > chi2) is 0.0000 for all models, indicating that the model fit is good. The empirical results indicate that farmers' access to infrastructure is negative and significant at the 1% level. The negative effect implies that not having access to the relevant infrastructure will decrease the farmers' chances of adopting CSIT. This is because for SHF to adopt and realize the benefits of adopting CSIT, they need to have access to physical infrastructure such as drip irrigation, water management structures, transport, markets, communication structures, and storage and processing structures [9,84]. Although in some cases SHF may construct their small dams in response to drought spells that result in crop failure, these dams are sometimes inadequate when supplying water in the field, as not much water is captured due to siltation [84].

Table 10. Logit regression results for the adoption barriers.

Adoption Challenges	Odds Ratio	Std. Err.	Z	P > z	95% Conf.	Interval
Age	0.9785732	0.0208532	−1.02	0.309	0.9385434	1.02031
Education	2.563328	2.63457	0.92	0.360	0.3419364	19.21601
Farming experience	1.009558	0.0441869	0.22	0.828	0.9265635	1.099986
Member of the irrigation scheme	7923403	0.5433404	−0.34	0.734	0.2066368	3.038196
Infrastructure	37.72841	36.41249	3.76	0.000 ***	5.690572	250.1388
Production costs	7.243408	4.541551	3.16	0.002 ***	2.119567	24.75361
High maintenance	0.0901258	0.0612009	−3.54	0.000 ***	0.0238139	0.3410883
Distance	1.023607	0.0111059	2.15	0.032	1.002069	1.045607
Cons	1.152442	1.242566	0.13	0.895	0.139268	9.536454

Notes: Statistically significant at the 10% level; statistically significant at the 5% level; *** statistically significant at the 1% level.

The estimated coefficient of production costs was negative and significant at the 1% level. This implies that adopting CSIT may be a challenge for SHF as it will add to their existing production costs. A CSIT often becomes a financial burden when farmers adopt technologies such as drip irrigation, which initially requires an initial investment. Such a decision is usually prohibitively expensive and risky for resource-poor farmers to undertake on their own because, in most cases, they have limited cash flows and rarely produce enough surplus that will enable them to purchase the technology [9].

The high maintenance of some CSIT was a positive and significant explanatory variable in this model at 1%. This indicates that an SHF has sufficient knowledge that some technologies could be challenging in terms of maintenance, thus enabling them to make their decision wisely. For instance, a farmer might select rooftop rainwater harvesting instead of drip irrigation, whereby troubleshooting or repairing might be a problem without proper experience or training.

5. Conclusions

Despite initial slow interest in CSIT, most SHF in the Capricorn district and a small proportion in the Vhembe district are adopting the technologies. This is often a result of the heterogeneity in terms of access to farm resources, technological inputs, and markets within the smallholder farming sector. This indicates a need for continued efforts to adapt the technological variants to fit the needs of farmers. Due to that, not considering relevant factors such as socio-economic factors has led to inappropriate targeting of the technology in areas with a lower likelihood of adoption. Results from this study suggest several barriers that should be used for better targeting the adopters and non-adopters of CSIT within the two districts.

First, the results indicated that low adoption might be linked to insufficient awareness, which is the initial stage of adopting any agricultural technology. This depends on the communication channels used by SHF in getting information about CSIT. Unfortunately, extension officers, often the primary source of information for SHF, were not accessible to non-adopters. Thus, they resort to other communication channels, which can sometimes delay the delivery of adequate information. This indicates that government and non-governmental organizations should invest more in creating awareness about CSIT to ensure that SHFs are sensitized. Although not a single channel has proven to not be the effective best for all situations in the communication process, agricultural extension officers should use a combination of communication channels when conveying agricultural messages. This will appeal to different human senses, thus aiding in easy understanding of messages. Due to that, this goal cannot be addressed by extension officers alone, as a result of being constrained by resources, the combined strength, and synergies of a pluralistic, multi-agency system in which the private sector, farmer organizations, cooperatives, NGOs, paraprofessionals, small agribusiness, self-help groups, input dealers and suppliers, electronic and print media and information technology is recommended. Each stakeholder will be able to contribute according to its strength and capabilities. Second, access to credit, often linked to land tenure, continues to be a significant barrier for rural farmers who want to adopt new agricultural technologies. The study found that access to credit was non-existent for most adopters and non-adopters. This is because their land tenure arrangements enable them to receive only PTO (permission to occupy) rather than a title deed. Due to that, most participants are also unwilling to invest their off-farm income and depend on government funding, which is unreliable. Therefore, for SHFs to function in an ever-growing and increasingly complex environment governed by the flow of funds controlled by banks, insurance companies, retailers, millers and traders, stakeholders should learn from formal financial institutions in developing countries. They have been successful in providing financial services to resource-poor entrepreneurs in agriculture. For instance, some of the recognized institutions include Agro-capital (Bolivia), Grameen Bank (Bangladesh), Basix Group (India) and Bank for Agriculture and Agricultural Co-operatives (BAAC, Thailand). This would ensure financial institutions such as Land banks consider assets and produce instead of collateral to expand the SHFs agricultural credit. Cooperatives, which government institutions and NGOs often recommend to reduce any individual uncertainty inherent to their economic activity by pooling their risks, have failed to address their financial challenges.

The result shows that although a high percentage of adopters and non-adopters indicated that they had been trained, it did not measure up to a level of adoption, particularly among the non-adopters. This can be associated with the training method used to introduce the farmers to the new technology. On-farm demonstrations often deliver the best results to ensure all the essential basics. This method lets farmers see first-hand how to operate and maintain the technology. In addition, demonstrations also create effective dialogue among the various stakeholders and farmers on important information such as irrigation scheduling, crop selection, fertilization, and market participation. However, extension officers should become learners, along with the farmers, to improve their knowledge and skills regarding CSIT. Therefore, it can be concluded that more focus should be on the Vhembe district, which revealed the lowest adoption of CSIT. Due to that, the agricultural sector in the district contributes 22.8% of Limpopo's GDP. The common occurrence of extreme weather conditions, such as droughts, floods and increasing temperature, along with the lack of interest among the young generation, will continue to have a devastating impact on smallholder farming activities, which has already been characterized by low productivity. In this context, CSIT would assist in empowering SHF to plan and cope with climate change impacts by focusing on community-led processes grounded in community priorities, needs, knowledge and capacities. Moreover, these technologies might also empower the older generation, who often have vast experience in farming activities, to incorporate their knowledge during the decision-making process to cope with the impacts of climate change.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analysed during the current study will be available from the corresponding author upon reasonable request.

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References

1. Hlatshwayo, S.I.; Ngidi, M.; Ojo, T.; Modi, A.T.; Mabhaudhi, T.; Slotow, R.A. Typology of the level of market participation among smallholder farmers in South Africa: Limpopo and Mpumalanga Provinces. *Sustainability* **2021**, *13*, 7699. [CrossRef]
2. Mwadzingeni, L.; Mugandani, R.; Mafongoya, P. Factors affecting the performance of the Tshiombo irrigation scheme in Limpopo Province, South Africa. *J. Agribus. Rural Dev.* **2020**, *3*, 269–277. [CrossRef]
3. Mazibuko, N.; Antwi, M.; Rubhara, T. Agricultural infrastructure as the driver of emerging farmers' income in South Africa. A stochastic frontier approaches. *Agron. Colomb.* **2020**, *38*, 261–271. [CrossRef]
4. Giller, K.E.; Delaune, T.; Silva, J.V.; van Wijk, M.; Hammond, J.; Descheemaeker, K.; van de Ven, G.; Schut, A.G.T.; Taulya, G.T.; Chikowo, R.; et al. Small farms and development in sub-Saharan Africa: Farming for food, for income or lack of better options. *Food Secur.* **2021**, *13*, 1431–1454. [CrossRef]
5. Ntshangase, N.L.; Muroyiwa, B.; Sibanda, M. Farmers' perceptions and factors influencing the adoption of no-till conservation agriculture by small-scale farmers in Zashuke, KwaZulu-Natal Province. Master's Thesis, University of Zululand, Empangeni, South Africa, 2016.
6. Myeni, L.; Moeletsi, M.E.; Nyagumbo, I.; Modiselle, S.; Mokoena, L.; Kgakatsi, I.B. Improving the food and nutritional security of smallholder farmers in South Africa: Evidence from the InnovAfrica project. *Sustainability* **2021**, *13*, 9902. [CrossRef]
7. Mkuhlani, S.; Crespo, O.; Rusere, F.; Zhou, L.; Francis, J. Classification of small-scale farmers for improved rainfall variability management in South Africa. *Agroecol. Sustain. Food Syst.* **2020**, *44*, 7–29. [CrossRef]
8. Pili, O.; Ncube, B. Smallholder farmer coping and adaptation strategies for agricultural water use during drought periods in the Overberg and West Coast Districts, Western Cape, South Africa. *Water* **2022**, *48*, 97–109.
9. Nakawuka, P.; Langanb, S.; Schmittera, P.; Barronc, J. A review of trends, constraints, and opportunities of smallholder irrigation in East Africa. *Glob. Food Sec.* **2017**, *1*, 2211–9124.
10. Williams, P.A.; Crespo, O.; Abu, M.; Simpson, N.P. A systematic review of how the vulnerability of smallholder agricultural systems to changing climate is assessed in Africa. *Environ. Res. Lett.* **2018**, *13*, 103004. [CrossRef]
11. Elum, Z.A.; Modise, D.M.; Marr, A. Farmer's perception of climate change and responsive strategies in three selected Provinces of South Africa. *Clim. Risk Manag.* **2017**, *16*, 246–257. [CrossRef]
12. Ubisi, N.R. Smallholder Farmers' Perceptions and Adaptation to Climate Change Interventions and Support Systems in Limpopo Province, South Africa. Master's Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa, 2016.
13. Pickson, R.B.; He, G. Smallholder farmers' perceptions, adaptation constraints, and determinants of adaptive capacity to climate change in Chengdu. *SAGE Open* **2021**, *1*, 21582440211032638. [CrossRef]
14. Teshome, H.; Tesfaye, K.; Dechassa, N.; Tana, T.; Huber, M. Smallholder farmers' perceptions of climate change and adaptation practices for maize production in Eastern Ethiopia. *Sustainability* **2021**, *13*, 9622. [CrossRef]
15. Shikwambana, S.; Malaza, N. Enhancing the resilience and adaptive capacity of smallholder farmers to drought in the Limpopo Province, South Africa. *Conservation* **2022**, *2*, 435–449. [CrossRef]
16. Batchelor, C.; Schnetzer, J. Concepts, Evidence, and Options for a Climate-Smart Approach to Improving the Performance of Irrigated Cropping Systems. Global Alliance for Climate-Smart Agriculture: Rome. 2018. Available online: http://www.fao.org/3/CA1726EN/ca1726en.pdf (accessed on 5 April 2021).
17. TNA Adaptation (2020) Barriers Analysis and Enabling Frameworks. Available online: https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2020/06/baef-ukraine-adaptation.pdf (accessed on 2 November 2022).
18. Musetha, M.A. The Impact of Climate Change on Agricultural Crop Production in the Vhembe District Municipality, Limpopo Province, South Africa. Ph.D. Thesis, University of South Africa, Pretoria, South Africa, 2016.
19. Agholor, A.I.; Nkosi, M. Sustainable water conservation practices and challenges among smallholder farmers in Enyibe Ermelo Mpumalanga Province, South Africa. *J. Agric. Educ. Ext.* **2020**, *2*, 112–123. [CrossRef]
20. Myeni, L.; Moeletsi, M. Factors determining the adoption of strategies used by smallholder farmers to cope with climate variability in the Eastern Free State, South Africa. *Agriculture* **2020**, *10*, 410. [CrossRef]
21. Adesina, A.A.; Chianu, J. Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. *Agrofor. Syst.* **2002**, *55*, 99–112. [CrossRef]
22. Zikhali, Z.M. Meeting the Extension Needs of Smallholder Farmers: The Climate Information Gap in the Public Agricultural Extension and Advisory Services in the Limpopo Province, South Africa. Ph.D. Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa, 2016.

23. Mufungizi, A.A.; Musakwa, W.; Gumbo, T. A land suitability analysis of the Vhembe district, South Africa: The case of maize and sorghum. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci-ISPRS Arch.* **2020**, *43*, 1024–1030. [CrossRef]
24. Kom, Z.; Nethengwe, N.S.; Mpandeli, S.; Chikoore, H. Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. *Geo J.* **2022**, *87*, 677–700. [CrossRef]
25. Murken, L.; Gornott, C. The importance of different land tenure systems for farmers' response to climate change: A systematic review. *Clim. Risk Manag.* **2022**, *35*, 100419. [CrossRef]
26. Mavhungu, T.J.; Nesamvuni, A.E.; Tshikolomo, K.A.; Raphulu, T.; Van Niekerk, J.A.; Mpandeli, N.S.; Nesamvuni, A.E. Characterization of women and youth smallholder agricultural entrepreneur's in rural irrigation schemes in Vhembe district, South Africa. *S. Afr. J. Agric. Ext.* **2021**, *49*, 104–122. [CrossRef]
27. Materechera, F.; Scholes, M.C. Characterization of farming systems using land as a driver of production and sustainability in the Vhembe District, Limpopo, South Africa. *J. Agric. Sci.* **2021**, *12*, 1352–1373. [CrossRef]
28. Baloyi, K.J. An Analysis of Constraints Facing Smallholder Farmers in the Agribusiness Value Chain: A Case Study of Farmers in the Limpopo Province. M Inst. Ph.D. Thesis, University of Pretoria, Pretoria, South Africa, 2010.
29. Mulaudzi, V.S. Determinants of Productivity among African Indigenous Vegetable Farmers in Vhembe District of Limpopo Province, South Africa. Ph.D. Thesis, North-West University, Mafikeng, South Africa, 2017.
30. Mutondwa, M.P.; Paramu, M.; Shenelle, L. Perceptions of climate change and drivers of insect pest outbreaks in vegetable crops in Limpopo Province of South Africa. *Climate* **2020**, *8*, 27.
31. Mpandeli, S.; Nhamo, L.; Moeletsi, M.; Masupha, T.; Magidi, J.; Tshikolomo, K.; Liphadzi, S.; Naidoo, D.; Mabhaudhi, T. Assessing climate change and adaptive capacity at the local scale using observed and remotely sensed data. *Weather Clim. Extremes* **2019**, *26*, 100240. [CrossRef]
32. Mahlangu, S.A.; Belete, A.; Hlongwane, J.J.; Luvhengo, U.; Mazibuko, N. Identifying potential markets for African leafy vegetables: A case study of farming households in Limpopo Province, South Africa. *Int. J. Agron. Agric.* **2020**, *1*, 8819295. [CrossRef]
33. Luvhengo, U.; Senyolo, M.P.; Belete, A. Socio-economic determinants of flock size in small-scale broiler production in Capricorn district of Limpopo Province, South Africa. *Hum. Ecol.* **2015**, *52*, 229–235. [CrossRef]
34. Mazwi, K.M. Adaptation of Smallholder Maize Farmers to Temperature and Rainfall Variability in Capricorn District Municipality, Limpopo Province, South Africa. Ph.D. Thesis, University of Limpopo Province, Turfloop, South Africa, 2019.
35. Stats-SA (Statistics-SA). *Mid-Year Population Estimates. Statistics South Africa (Stats SA), Statistical Release P0302*; Stats-SA: Pretoria, South Africa, 2015.
36. Limpopo Province. Agri-Hubs Identified by the Limpopo Province. 2015. Available online: https://www.dalrrd.gov.za (accessed on 13 December 2022).
37. Galal, S. Number of People Employed in Agriculture in South Africa Q4 2020, by Region. 2021. Available online: https://www.statista.com/statistics/1129828/number-of-people-employed-in-agriculture-in-south-africa-by-region/ (accessed on 9 December 2022).
38. Limpopo Information Directory. Available online: https://www.limpopo-info.co.za/ (accessed on 5 November 2022).
39. Mashaphu, M.P. Analysing Factors Affecting the Participation of Small-Scale Cattle Farmers in Livestock Auctions in the Capricorn District of Limpopo Province. Ph.D. Thesis, University of Limpopo, Turfloop, South Africa, 2021.
40. Rasimphia, T.E.; Tinarwoa, D. Relevance of biogas technology to Vhembe district of the Limpopo Province in South Africa. *Biotechnol. Rep* **2020**, *25*, e00412. [CrossRef] [PubMed]
41. Rusliya, M. Binary logistics regression model to analyze factors influencing technology adoption processes of vegetable farmers case in central Java Indonesia. In Proceedings of the International Symposium Southeast Asia Vegetables 2021 (SEAVEG 2021), Yogyakarta, Indonesia, 18–20 November 2022; Rusliyadi, M., Ardi, Y.W.Y., Winarno, K., Eds.; Atlantis Press: Paris, France; pp. 460–470.
42. Serote, B.; Mokgehle, S.; Du Plooy, C.; Mpandeli, S.; Nhamo, L.; Senyolo, G. Factors influencing the adoption of climate-smart irrigation technologies for sustainable crop productivity by smallholder farmers in arid areas of South Africa. *Agriculture* **2021**, *11*, 1222. [CrossRef]
43. Güner, R.; Hasanoğlu, I.; Aktaş, F. Covid-19: Prevention and control measures in the community. *Turk. J. Med. Sci* **2020**, *50*, 571–577. [CrossRef]
44. Cheteni, P. Barriers and Incentives to Potential Adoption of Biofuel Crops by Smallholder Farmers in Selected Areas in the Chris Hani and O.R Tambo District Municipalities, South Africa. Ph.D. Thesis, University of Fort Hare, Alice, South Africa, 2014.
45. Shange, N.S.Q. Socio-Economic Factors Influencing the Adoption of in-Field Rainwater Harvesting Technology for Enhancing Household Food Security by Smallholder Farmers in the Nkonkobe Municipality, Eastern Cape Province. Ph.D. Thesis, University of Fort Hare, Alice, South Africa, 2015.
46. Gwambene, B.; Saria, J.A.; Jiwaji, N.T.; Pauline, N.M.; Msofe, N.K.; Mussa, K.R.; Tegeje, J.A.; Messo, I.; Mwanga, S.S.; Shija, S.M.Y. Smallholder Farmers' Practices and Understanding of Climate Change and Climate Smart Agriculture in the Southern Highlands of Tanzania. *JRDM* **2015**, *13*, 37–47.
47. Addis, Y.; Abirdew, S. Smallholder farmers' perception of climate change and adaptation strategy choices in Central Ethiopia. *Int. J. Clim. Change Strateg. Manag.* **2021**, *13*, 463–482. [CrossRef]

48. Mgendi, G.; Mao, S.; Qiao, F. Does the training program sufficient to improve the smallholder farmers' productivity in Africa? Empirical evidence from the Chinese agricultural technology demonstration centre in Tanzania. *Sustainability* **2021**, *13*, 1527. [CrossRef]
49. Shaw, C.S. Agricultural Technology Adoption in West Africa. Ph.D. Thesis, Texas A& M University, College Station, TX, USA, 2014.
50. Popoola, O.O.; Yusuf, S.F.G.; Monde, N. Information sources and constraints to climate change adaptation amongst smallholder farmers in Amathole district municipality, Eastern Cape Province, South Africa. *Sustainability* **2020**, *12*, 5846. [CrossRef]
51. Cheboi, S.; Mberia, H. Efficacy of interpersonal communication channels in the diffusion and adoption of zero grazing technology. *Int. J. Acad. Res.* **2014**, *4*, 352–368. [CrossRef] [PubMed]
52. Kelil, A.; Girma, Y.; Hiruy, M. Access and use of agricultural Information in Africa: A conceptual review. *J. Inf. Knowl. Manag.* **2020**, *10*, 1–5.
53. Elia, E. Farmers' awareness and understanding of climate change and variability in central semi-arid Tanzania. *Univ. Dar Salaam Libr. J.* **2017**, *12*, 124–138.
54. Colussi, J.; Morgan, E.L.; Schnitkey, G.D.; Padula, A.D. How communication affects the adoption of digital technologies in soybean production: A survey in Brazil. *Agriculture* **2022**, *12*, 611. [CrossRef]
55. Udimal, T.B.; Jincai, Z.; Mensah, O.S.; Caesar, A.E. Factors influencing the agricultural technology adoption: The case of improved rice varieties (Nerica) in the Northern Region, Ghana. *J. Econ. Sustain. Dev.* **2017**, *8*, 137–148.
56. Churi, A.J.; Mlozi, M.R.S.; Siza, D.; Tumbo, S.D.; Casmir, R. Understanding farmers' information communication strategies for managing climate risks in rural semi-arid areas, Tanzania. *Int. J. Inf. Technol.* **2012**, *2*, 838–845.
57. Njenga, M.W.; Mugwe, J.N.; Mogaka, H.; Nyabuga, G.; Kiboi, M.; Ngetich, F.; Mucheru-Muna, M.; Sijali, I.; Mugendi, D. Communication factors influencing adoption of soil and water conservation technologies in the dry zones of Tharaka-Nithi County, Kenya. *Heliyon* **2021**, *7*, e08236. [CrossRef]
58. Yang, G.; Duanyang, Z.; Yuc, L.; Yang, H. Influence of a new agricultural technology extension mode on farmers' technology adoption behaviour in China. *J. Rural Stud.* **2020**, *76*, 173–183.
59. Oyetunde-Usman, Z.; Olagunju, K.O.; Ogunpaimo, O.R. Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *Int. Soil Water Conserv. Res.* **2021**, *9*, 241–248. [CrossRef]
60. Moremedi, G.; Hulela, K.; Maruatona, T.L. Factors perceived to influence the adoption of improved technologies in arable farming in the southern district of Botswana. *Int. J. Agric. Ext.* **2018**, *6*, 193–202. [CrossRef]
61. Suleiman, R.A.; Abdulrahman, S.; Ariyo, O.C.; Adelani, O.D. Farmer's perception of the effectiveness of extension communication channels in the dissemination of Agro-forestry Technologies in Ekiti state, Nigeria. *AJST* **2021**, *5*, 639–646.
62. Muriuki, N.; Munyua, C.; Wanga, D. Communication channels in the adoption of technology with a focus on the use of purdue improved crop storage (PICS) among small-scale maize farmers in Kenya. *J. Biol. Agric. Healthc.* **2016**, *6*, 8–12.
63. Ziba, D. The Impact of Irrigation Schemes on Farmers' Income and Livelihoods in the Upper East Region of Ghana. Master's Thesis, Kwame Nkrumah University of Science and Technology, Kabwe, Zambia, 2015.
64. Kalkidan, F.B. The Role of Gender in Small-Scale Irrigation Agriculture among Smallholder Farmers in Lume District in the Central Rift Valley of Ethiopia. Ph.D. Thesis, Hawassa University, Awasa, Ethiopia, 2016.
65. Moyo, T. The Contribution of Smallholder Irrigation Farming to Rural Livelihoods and the Determinants of Benefit Distribution: The Case of Limpopo Province of South Africa. Ph.D. Thesis, University of Pretoria, Pretoria, South Africa, 2016.
66. Mzuyanda, C. Analysis of the Impact of Smallholder Irrigation Schemes on the Choice of Rural Livelihood Strategy and Household Food Security in Eastern Cape Province. Ph.D. Thesis, University of Fort Hare, Alice, South Africa, 2017.
67. Awinda, D.O. The socio-economic impacts of irrigated smallholder agriculture on sustainable household food security in Kenya. *Kabar. J. Res. Innov.* **2018**, *6*, 1–15.
68. Kibirige, D. A comparison of estimated maize and cabbage enterprise budgets of ideal small-scale commercial and subsistence farms in the Eastern Cape Province of South Africa. *Int. J. Econ. Commer. Manag.* **2014**, *2*, 1–14.
69. Anuga, S.W.; Gordon, C.; Boon, E.; Surugu, M.I.J. Determinants of climate-smart agriculture (CSA) adoption among smallholder food crop farmers in the Techiman Municipality, Ghana. *Ghana J. Geogr.* **2019**, *11*, 124–139.
70. Lugamara, C.B. Effectiveness of Communication Channels and Smallholder Farmers' Adoption of Improved Legume Technologies: A Case of Morogoro Region, Tanzania. Ph.D. Thesis, Sokoine University of Agriculture, Morogoro, Tanzania, 2017.
71. Owombo, P.T.; Idumah, F.O.; Akinola, A.A.; Ayodele, O.O. Does land tenure security matter for the adoption of sustainable agricultural technology? Evidence from agroforestry in Nigeria. *J. Sustain. Dev. Afr.* **2015**, *17*, 65–82.
72. Streck, C.; Burns, D.; Guimaraes, L. *Incentives and Benefits for Climate Change Mitigation for Smallholder Farmers CCAFS Report no. 7. CGIAR Research Program on Climate Change*; Agriculture and Food Security (CCAFS): Copenhagen, Denmark, 2012; Available online: www.ccafs.cgiar.org (accessed on 14 February 2022).
73. MCcosh, J.; Dedekind, L.; Ntombela, Z.; Khuzwayo, M.; Letty, B.; Shezi, Z.; Bambalele, N.; Gasa, N.; Everson, T.; Everson, C.; et al. Upscaling Rainwater Harvesting and Conservation on Communal Crops and Rangeland through Integrated Crop and LIVESTOCK Production for Increased Water Use Productivity. WRC Report No. TT 712/16. 2017. Available online: https://www.wrc.org.za/Wp-Content/Uploads/Mdocs/Tt%20712-17%20web.pdf (accessed on 16 March 2022).
74. Oyetunde-Usman, Z. Heterogeneous factors of adoption of agricultural technologies in West and East Africa countries: A Review. *Front. Sustain. Food. Syst.* **2022**, *6*, 1–14. [CrossRef]

75. Kasimbazi, E. Land Tenure and Rights for Improved Land Management and Sustainable Development. Global Land Outlook Working Paper. 2017. Available online: https://www.unccd.int/sites/default/files/2018-06/5.%20Land%2BTeure%2Band%2BRights__E_Kasimbazi.pdf (accessed on 18 April 2022).
76. Oladele, O.I.; Mudhara, M. Empowerment of Women in Rural Areas through Water Use Security and Agricultural Skills Training for Gender Equity and Poverty Reduction in Kwazulu-Natal and North West Province. WRC Report No. TT 2176/1/16. 2016. Available online: https://www.wrc.org.za/wp-content/uploads/mdocs/2176-1-16.pdf (accessed on 11 January 2022).
77. Pratiwi, A.; Suzuki, A. Does training location matter? Evidence from a randomized field experiment in Rural Indonesia. *Agric. Food Econ.* **2020**, *8*, 3. [CrossRef]
78. Miheretu, B.A.; Yimer, A.A. Determinants of farmers' adoption of land management practices in Gelana sub watershed Northern highlands of Ethiopia. *Ecol. Process.* **2019**, *6*, 19. [CrossRef]
79. Du Plessis, F.J.; van Averbeke, W.; van der Stoep, I. Micro-Irrigation for Smallholders: Guidelines for Funders, Planners, Designers, and Support Staff in South Africa. WRC Report No. TT 164/01. 2002. Available online: https://www.wrc.org.za/wp-content/uploads/mdocs/TT-164-01.pdf (accessed on 18 March 2022).
80. Cafer, A.M.; Rikoon, J.S. Adoption of new technologies by smallholder farmers: The contributions of extension, research institutes, cooperatives, and access to cash for improving teff production in Ethiopia. *Agric Hum. Values* **2018**, *35*, 685–699. [CrossRef]
81. Tshwene, S.C. Training Needs Analysis of Women in Irrigation Farming in the North West Province, South Africa. Ph.D. Thesis, North-West University, Potchefstroom, South Africa, 2019.
82. Ndibalema, G. Effective Communication for Disseminating Soil and Water Management Practices to Bring about Sustainable Smallholder Agriculture in Tanzania: A Case Study of Manyara and Dodoma Regions. Ph.D. Thesis, Wageningen University and Research, Wageningen, The Netherlands, 2019.
83. Plantinga, A.W. The Effects of Social Learning and Market Participation on Technology Adoption: A Study on Extension and Marketing Services at a Farmers' Association in Zambia. Master's Thesis, Wageningen University and Research, Wageningen, The Netherlands, 2018.
84. Mugiya, D.; Hofisi, C. Climate change adaptation challenges confronting small-scale farmers. *Environ. Econ.* **2017**, *8*, 57–65. [CrossRef]