water

MDPI

Article

Examining the Barriers to Redesigning Smallholder Production Practices for Water-Use Efficiency in Numbi, Mbombela Local Municipality, South Africa

Mishal Trevor Morepje *, Isaac Azikiwe Agholor, Moses Zakhele Sithole, Nomzamo Sharon Msweli, Variety Nkateko Thabane and Lethu Inneth Mgwenya

School of Agriculture, University of Mpumalanga, Mbombela 1200, South Africa; isaac.agholor@ump.ac.za (I.A.A.); moses.sithole@ump.ac.za (M.Z.S.); 201836335@ump.ac.za (N.S.M.); 201988429@ump.ac.za (V.N.T.); 201971976@ump.ac.za (L.I.M.)

* Correspondence: morepjetrevor@gmail.com

Abstract: Smallholder farmers in South Africa face issues related to water shortages and poor irrigation water management. This study investigated barriers to improving water-use efficiency (WUE) in smallholder production practices in Numbi, South Africa. The objectives were to identify barriers in redesigning production practices for higher agricultural productivity and analyze the relationship between irrigation water supply and the adoption of WUE methods. From a population of 7696 people, 141 smallholder farmers were sampled using a simple random sampling technique through Taro Yamane's sample size formula. The data were analyzed using Pearson's correlation coefficient and descriptive statistics. Unreliable water supply (M = 3.78, SD = 0.85), poor soil water retention (M = 3.78, SD = 0.85), lack of water-efficient irrigation systems (M = 3.91, SD = 0.71), lack of water storage facilities (M = 3.85, SD = 0.93), limited access to credit (M = 4.09, SD = 0.85), income instability due to market fluctuations (M = 3.96, SD = 0.91), inadequate knowledge of irrigation management (M = 4.00, SD = 0.84), and harsh climatic factors were identified. A positive correlation (r = 0.339, n = 141, $p < 0.001$) between irrigation water source and WUE techniques was evident, indicating that irrigation water source had an insignificant impact on WUE methods. Resolving these barriers requires a holistic approach focusing on investments in irrigation infrastructure and targeted education initiatives by extension agents and other stakeholders, as this can enhance agricultural productivity.

Keywords: water-use efficiency (WUE); smallholder farming; water shortages; sustainable farming

Citation: Morepje, M.T.; Agholor, I.A.; Sithole, M.Z.; Msweli, N.S.; Thabane, V.N.; Mgwenya, L.I. Examining the Barriers to Redesigning Smallholder Production Practices for Water-Use Efficiency in Numbi, Mbombela Local Municipality, South Africa. *Water* **2024**, *16*, 3221. https://doi.org/10.3390/w16223221

Academic Editors: Hui Yang, Manoj K. Shukla and Yusen Yuan

Received: 23 September 2024
Revised: 5 November 2024
Accepted: 7 November 2024
Published: 9 November 2024

1. Introduction

Water shortage is a major worldwide issue, with far-reaching consequences for agriculture, particularly in drought-prone areas [1]. Smallholder farmers in South Africa confront considerable problems owing to limited water supplies and poor water usage techniques [2]. These farmers, who play an important role in the country's food security and rural livelihoods, are frequently hampered by outdated production practices that do not maximize water usage [3]. As a result, there is an urgent need to restructure existing production practices to improve water efficiency, ensure sustainable agricultural practices, and increase resilience to climate unpredictability.

Smallholder farmers who rely heavily on rain-fed agriculture are especially vulnerable to the effects of climate change [4]. The country's inconsistent rainfall patterns and periodic droughts increase water shortages, making smart water usage not only advantageous but also required for the survival of these farming communities [5]. However, shifting to more water-efficient agriculture practices has several hurdles, ranging from economic and technological barriers to social and policy restraints [6].

Studies [7–9] on water-use efficiency in smallholder farming emphasize the technological and agronomic (soil management, crop production, and water management) benefits, rather than conducting in-depth research on how socioeconomic factors such as access to finance and social and cultural attitudes influence the adoption of WUE practices. Moreover, the long-term sustainability and adaptability of these practices in varying environmental and socioeconomic contexts should be further explored.

Despite the widely acknowledged need for increased water-use efficiency in agricultural practices, smallholder farmers confront several challenges in redesigning their production practices for water-use efficiency (WUE). These limitations include a lack of financial resources, poor access to technology, and insufficient knowledge and training in current water-efficient practices. Institutional concerns such as inadequate assistance from agricultural extension agencies and poor infrastructure also restrict success in redesigning production practices for WUE [10].

Furthermore, approximately 60% of the water used nationally in South Africa is used for farming [11]. Putting into practice effective water management techniques is essential to guarantee food security and sustainable agriculture [12]. A framework for water conservation and demand management is provided by the National Water Policy and National Water and Sanitation Master Plan [13]. Studies [12,14] have shown that smallholder farmers in South Africa use a variety of water management techniques, such as mulching, drip irrigation, crop selection and rotation, rainwater harvesting, and conservation tillage. These strategies minimize water loss, boost crop yields, and improve resilience to drought [15]. Despite the difficulties smallholder farmers face in managing water resources, smallholder farmers are essential to the country's food security and livelihoods [16].

Water-use efficiency measures are difficult for smallholder farmers to implement, despite their many advantages. Major obstacles include poor infrastructure, inadequate training and capacity building, and limited access to financing and technology [17]. These difficulties are made worse by climate unpredictability and change, which makes it harder for smallholder farmers to adjust to shifting weather patterns. Furthermore, industry and urbanization's conflicting demands for water strain already-limited water supplies [18]. In smallholder agriculture, the significance of water-use efficiency cannot be emphasized enough. Effective water management strategies boost agricultural yields and quality. Moreover, they further cut down on waste and water loss and boost resistance to drought and climate change, according to research [19]. Additionally, WUE also helps to save water for future generations, enhances sustainable agriculture, and enhances food security and livelihood [20].

Research depicts that in South Africa, smallholder farming suffers greatly from water scarcity [14,18]. Some of the effects include lower agricultural yields and productivity, a rise in food insecurity and poverty, and a loss of livelihood and income. Additional impacts are a decline in water quality and ecosystem health, and more competition for scarce water resources [21]. Therefore, recognizing the value of conserving water and using it effectively, the South African government has put regulations and initiatives in place to support sustainable water management techniques [22].

Moreover, smallholder water management techniques play a vital role in guaranteeing South Africa's food security and sustainable agriculture. Investments in water infrastructure, capacity building, and policy support are necessary to address issues and advance water-use efficiency techniques. The development of context-specific tactics and solutions to assist smallholder farmers in efficiently managing water resources should be the main emphasis of future research.

In conclusion, the early 1970s saw several worldwide water crises, which is when the idea of water conservation first emerged. Even twenty years ago, there were around 200 definitions of water conservation in written works [23], demonstrating the definition's contextual dependence. The 2021 annual report on the state of water scarcity in the world is where the term "water conservation" is currently understood to originate from. It is the practice of using water efficiently to reduce unnecessary water usage [24]. The Theory of Farmers' Active Participation in Water Conservation evolved due to the extreme volatility of agricultural commodity prices and the turmoil in the currency and energy markets at the time; the concept of water conservation was initially centered on ensuring food availability and the price stability of basic foods [25]. This theory, which emphasized the crucial needs and behavior of potentially susceptible and affected individuals, was necessary considering the incidence of famine, hunger, and water crises [26]. Its purpose was to identify and analyze the factors contributing to water scarcity to come up with collective solutions for the agricultural community.

Therefore, this study sought to investigate the socioeconomic factors that influence smallholder farmers' ability to adopt WUE practices in their production practices. The overall research question for the study is "*What are the key barriers to redesigning smallholder production practices for improved water-use efficiency*?" The overall research goal is to identify and analyze factors hindering water-efficient practices among smallholder farmers, thereby providing insights to inform policy and extension support. Specifically, the study objectives were to (1) assess the socioeconomic factors affecting smallholder farmers, (2) examine the barriers to adopting water-use efficient practices, and (3) evaluate the correlation between primary irrigation water sources and the implementation of water-use efficiency practices at the study area.

2. Materials and Methods

2.1. Study Site

Numbi (Figure 1) is a rural community situated near the Numbi-gate Kruger National Park entrance and forms part of communities under the Mbombela Local Municipality, a local municipality in Mpumalanga province (MP), South Africa (RSA). The geographical coordinates of the study area are 25°07′39.8″ S 31°09′44.9″ E.

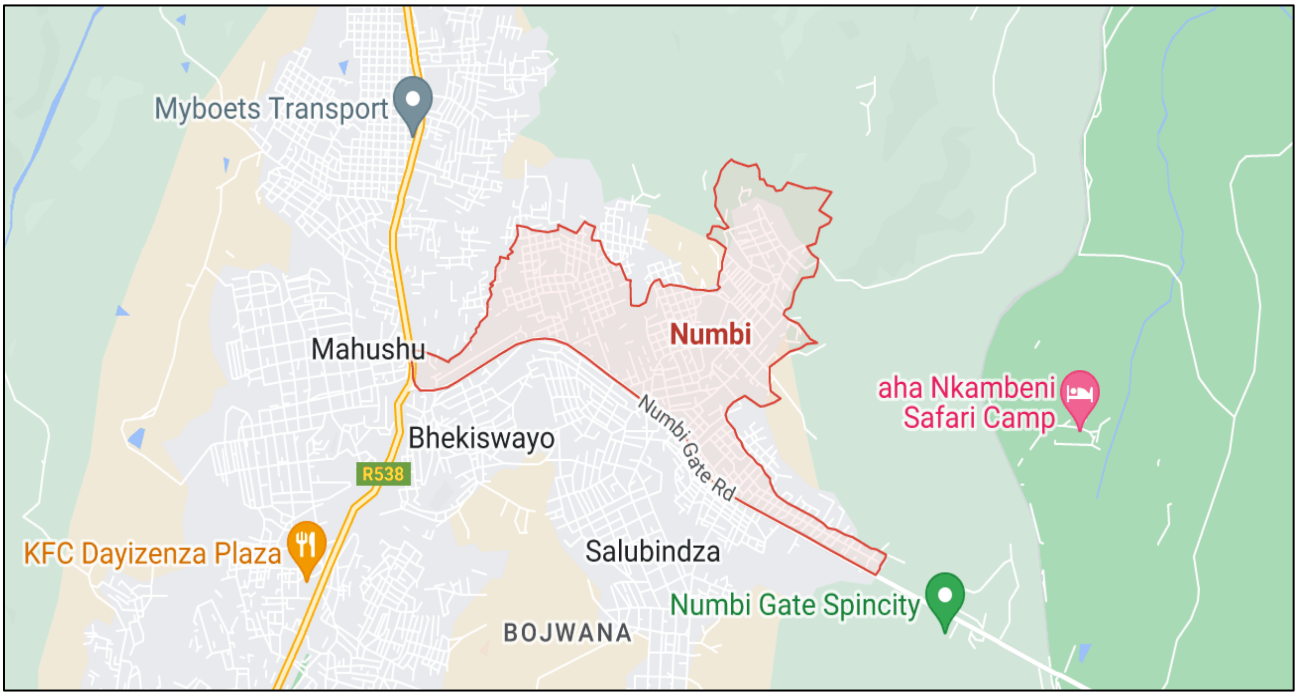

Figure 1. Map of Numbi, Mbombela Local Municipality [14].

The statistical report compiled by [27] states that the size of the rural community is 4.57 km^2, comprising 7696 people and 1932 households. Furthermore, the dominant racial group is Africans, who make up 99 per cent of the community, and 94 per cent are of the Swati tribe [14,27]. The main economic activity is farming, with most of the households having backyard gardens consisting of seasonal crops, subtropical fruit trees, and nuts such as macadamia.

2.2. Study Design

The study followed a quantitative approach using a survey. A structured questionnaire was used to gather information from participants. The survey data focused on participants' perspectives on barriers in redesigning smallholder production practices for WUE, the utilization of water-efficient methods within the study area, challenges limiting farmers' capacity to restructure their production practices, and their willingness to embrace formal water management systems.

2.3. Sampling Method and Sample Size

In this study, a simple random sampling method was employed to select participants from the entire population of farmers, estimated to be 217. The sample size for this study consisted of 141 respondents, determined using Taro Yamane's formula for sample size calculation. The equation used is as follows, where n = size of the sample (141), N = total population (217), and e = margin of error (0.05):

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

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

$$n = 141$$

2.4. Data Collection

A structured questionnaire was utilized to gather quantitative data. This questionnaire was specifically designed to collect information relevant to the achievement of the study aim and objectives. The questions were predominantly focused on exploring the barriers in redesigning production practices for WUE and to assess the correlation between the primary irrigation water source for smallholder farmers and the application of WUE approaches by smallholder farmers.

The five-point Likert scale ranged from 1 to 5 and it was used to obtain information from respondents in relation to the barriers faced in redesigning their production practices for WUE. Participants were asked to respond to barriers they face in redesigning their production practices for higher agricultural productivity by choosing the following response items: strongly disagree (1), rarely disagree (2), disagree (3), agree (4), and strongly agree (5).

2.5. Data Analysis

The data analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 28. Descriptive statistics (mean and standard deviation) were used for the primary analysis of the responses provided by the participants. The means obtained for each barrier in redesigning production practices for WUE were interpreted using the Likert scale interval, as shown in Table 1, and the intervals are obtained by using the interval level calculation formula as follows: Interval level = [Greatest value (5) − smallest value (1)]/number of points (5) = 0.8. Therefore, the mean interval for strongly disagree (1) = 1.00–1.80, rarely disagree (2) = 1.81–2.60, disagree (3) = 2.61–3.40, agree (4) = 3.41–4.20, and strongly agree (5) = 4.21–5.00.

The Pearson correlation coefficient test was used to measure the correlation between irrigation water supply and the adoption of WUE approaches. The primary irrigation water sources included municipal water, rainfall, water streams, and well/borehole, while the WUE approaches were irrigation scheduling, drought-resistant crops, dry-land farming, mulching, and rainwater harvesting.

Table 1. Likert scale mean interval and value (adapted from Bukhari [28]).

Opinion	Value	Mean Interval
Strongly disagree	1	1.00–1.80
Rarely disagree	2	1.81–2.60
Disagree	3	2.61–3.40
Agree	4	3.41–4.20
Strongly agree	5	4.21–5.00

3. Results

3.1. Socioeconomic Factors of Smallholder Farmers in Numbi

The socioeconomic factors of farmers in the study area with respect to gender, age, formal educational level, farming experience, and farming methods are presented below. Considering gender and age when redesigning production practices for water-use efficiency (WUE) is vital as these factors influence resource access and the adoption of new technologies. Males and females often have different social and cultural roles that can lead to women facing barriers to implementing water-efficient practices. Age also affects the willingness of smallholder farmers to embrace innovation. The level of formal education influences smallholder farmers' ability to adopt WUE practices. Farmers with higher education are more likely to understand and implement new technologies, while those with less education may face challenges in accessing or operating complex technology [14].

Therefore, the study found that female smallholder farmers make up 63% of respondents surveyed, as shown in Figure 2a, and Figure 2b depicts that 90% of the smallholder farmers are more than 29 years of age, with about 40% of the smallholder farmers being above the age of 59 years old. By referring to Figure 3, the literacy (formal education level) within the study area is encouraging, with 52% of the sampled smallholder farmers having been exposed to secondary and post-secondary school education and nearly a third (28%) having attended primary school education.

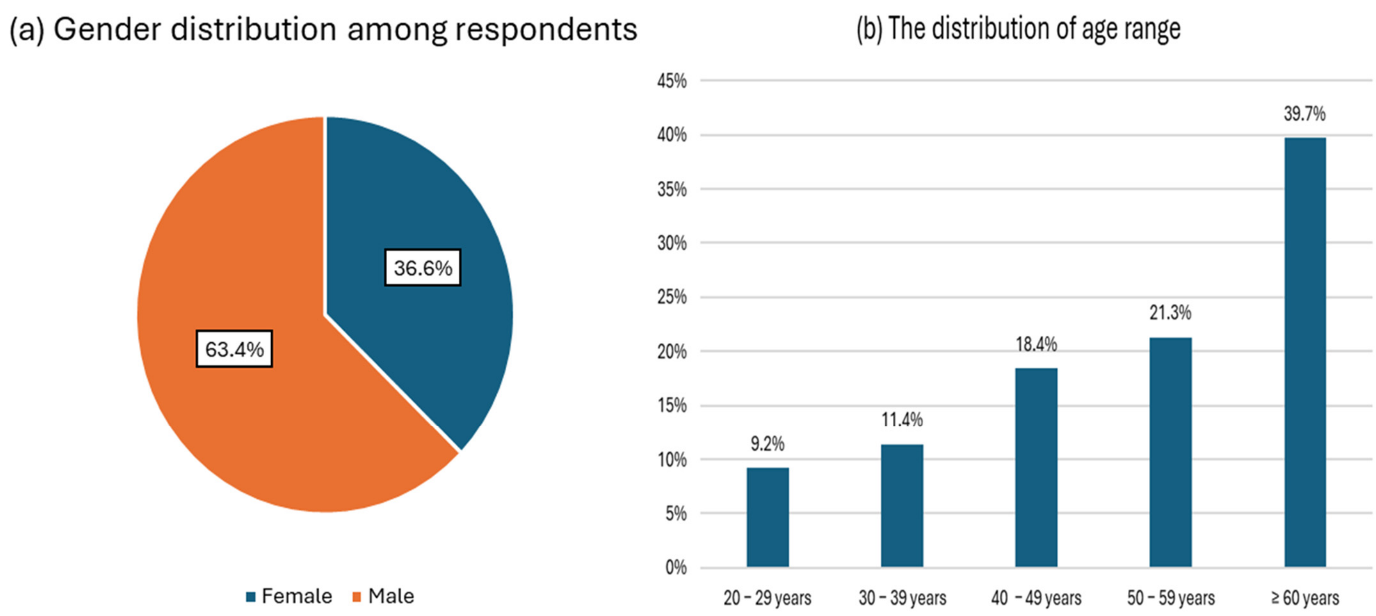

Figure 2. Gender distribution (**a**) and the distribution of age among respondents (**b**).

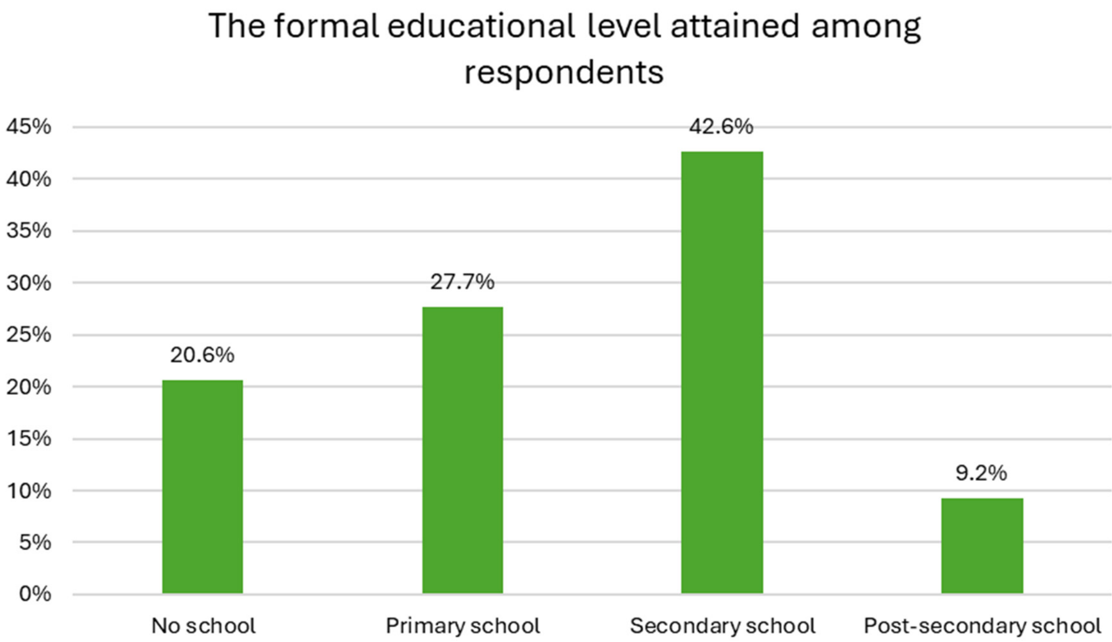

Figure 3. The level of formal education attained by smallholder farmers surveyed.

Farming experience plays a key role in how farmers adopt new water-use efficiency (WUE) practices. Experienced farmers may have deeper knowledge of their environment and traditional farming practices, which can influence their willingness to adopt WUE practices. Meanwhile, farmers with less experience can be more willing to adopt WUE practices yet might lack practical skills and knowledge. Regarding farming experience among the sampled smallholder farmers, as illustrated in Figure 4, merely 6% of the smallholder farmers have 1 year or less of farming experience, with 75% of the farmers having more than 5 years of farming experience.

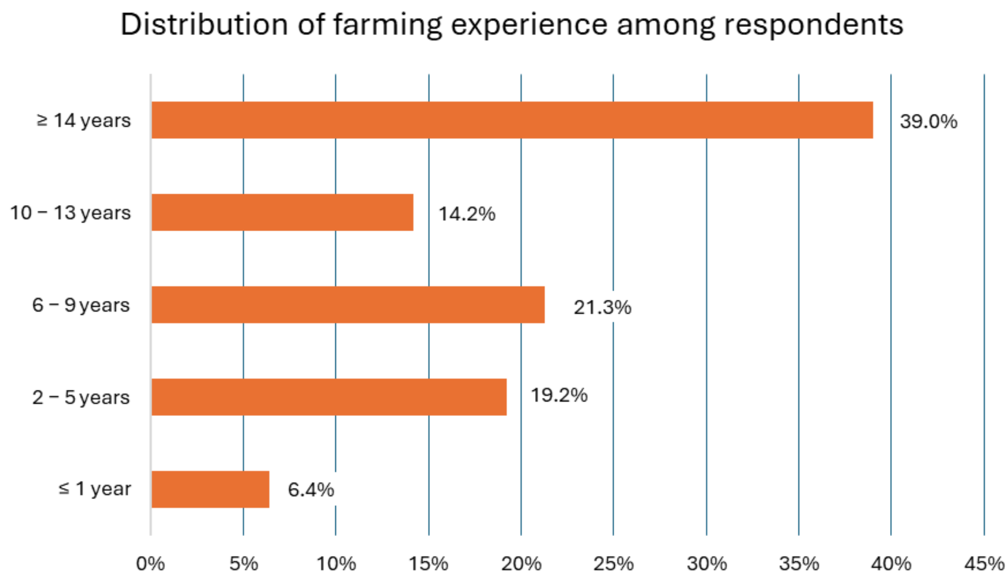

Figure 4. A representation of the distribution of farming experience among farmers.

Access to off-farm income is important when considering WUE practices among smallholder farmers. Farmers with off-farm income may have more financial resources to invest in modern irrigation technologies or improvements in their farming systems. In contrast, those relying solely on farming might struggle to afford such investments. Thus, the findings (Figure 5) show that most smallholder farmers (84%) in the study area receive income from non-farming organizations or entities, with 16% of smallholder farmers relying solely on farming as an income stream.

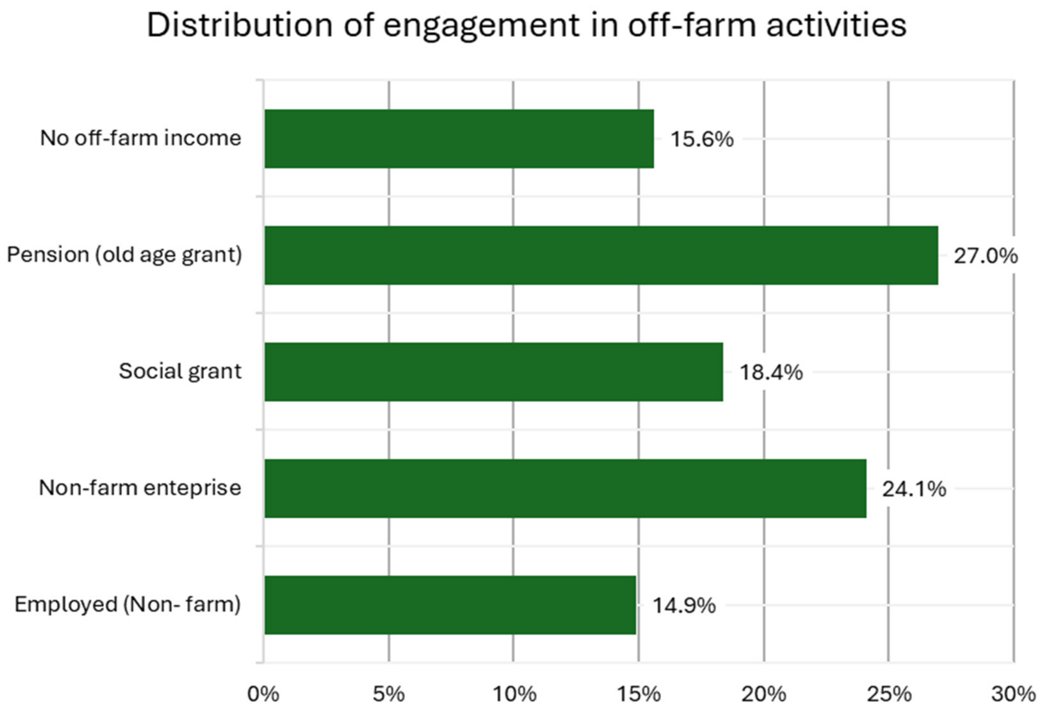

Figure 5. Varying sources of off-farm income and its distribution among farmers.

Smallholder farmers using WUE practices demonstrate that they recognize the importance of conserving water and optimizing its use for crop production. Their choice of WUE methods indicates an awareness of water scarcity challenges and the benefits of improving water management for sustainable farming. Based on the survey results in Figure 6, smallholder farmers value WUE approaches such as mulching (20%) and irrigation scheduling (23%), with rainwater harvesting (46%) ranking the highest. Drought-resistant crops (3%) and dry-land farming (8%) are used by fewer smallholder farmers when compared to the other approaches.

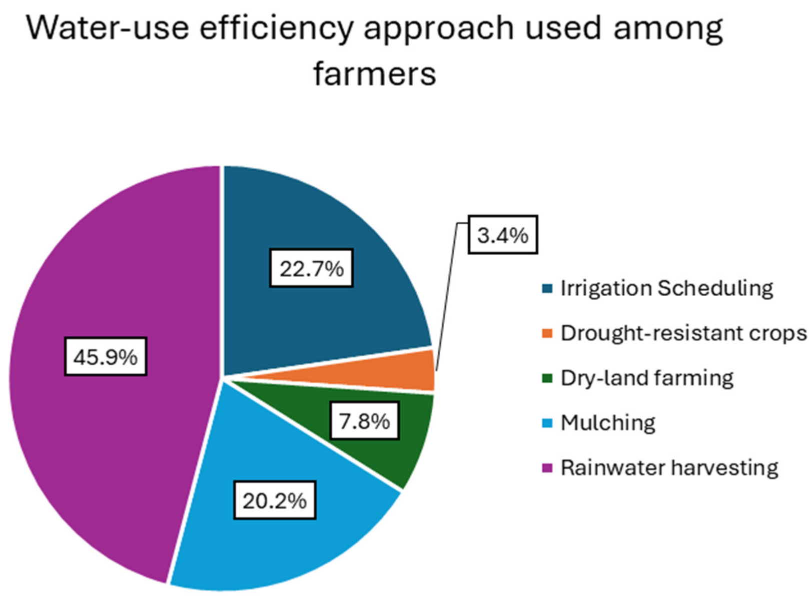

Figure 6. The WUE approaches used by farmers and their distribution.

The distribution of primary irrigation water sources as presented in Figure 7 for smallholder farmers is municipal water at 41%, rainfall at 21%, water streams at 29%, and lastly wells/boreholes at 9%. The data in Figure 7, with respect to the main irrigation water sources used by smallholder farmers, show a strong reliance on municipal water (41%) and the communal water stream (29%). Farmers relying on reliable sources like water streams and boreholes/wells are more likely to have flexibility in their water management practices, while those depending on rainfall or streams may face greater challenges in water availability. Farmers that experience scarce or unpredictable water supply are more likely to adopt efficient technologies.

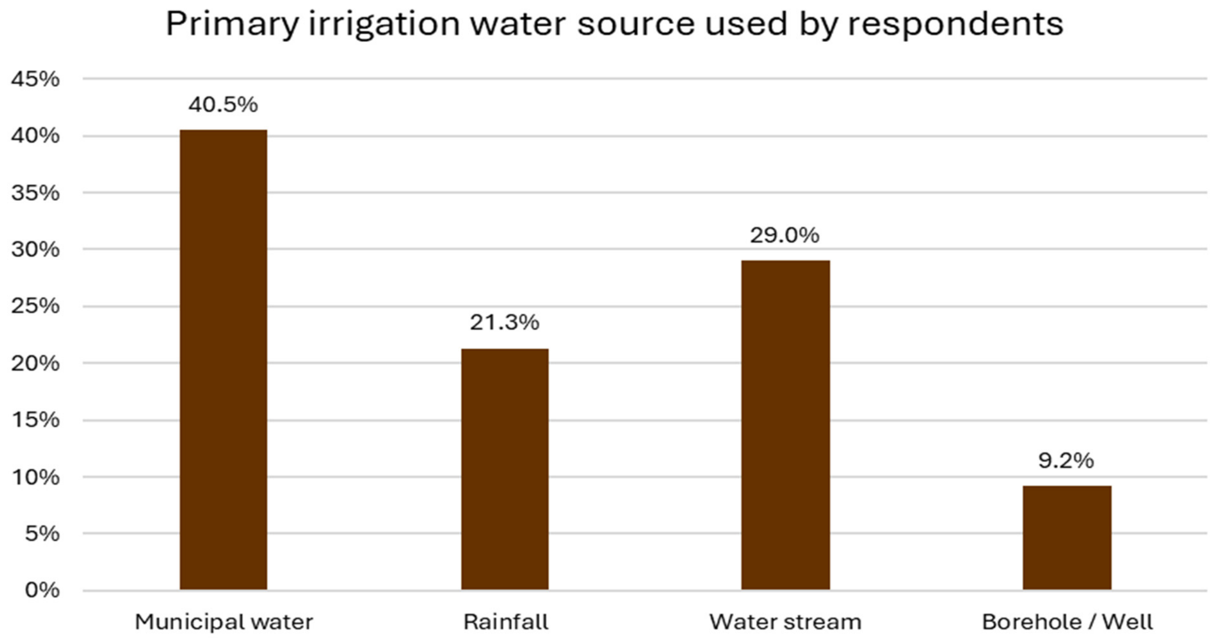

Figure 7. Primary irrigation water sources used by smallholder farmers.

With regard to the irrigation systems preferred by smallholder farmers in the study area, manual irrigation (watering cans) (55%) is the most preferred as shown in Figure 8, followed by sprinkler (15%), rain-fed (15%), and surface irrigation systems (13%), with micro-irrigation systems (2%) being the least used. The irrigation systems that farmers use significantly impact their WUE practices. Different irrigation systems, such as drip irrigation, sprinkler systems, or traditional flood irrigation, have varying levels of efficiency in water application and usage. Farmers using advanced systems like drip irrigation can achieve higher WUE due to precise water delivery, reducing waste and enhancing crop yields.

3.2. Distribution of Barriers in Redesigning Production Practices

The barriers faced by smallholder farmers in redesigning their production practices for WUE among smallholder farmers in the study area are presented in Table 2. The presented findings shed light on several crucial obstacles that smallholder farmers must overcome to restructure their production practices for WUE. Based on the overall mean given for each challenge in Table 3, the smallholder farmers agree to lacking reliable water supply (M = 3.78; SD = 0.85), having soils with poor water-holding capacity (M = 3.78; SD = 0.85), having absent water-efficient irrigation systems (M = 3.91; SD = 0.71), having a lack of water storage systems/facilities (M = 3.85; SD = 0.93), having no access to credit (M = 4.09; SD = 0.85), having inconsistent income due to unreliable markets (M = 3.96; SD = 0.91), having insufficient knowledge on irrigation water management (M = 4.00; SD = 0.84), and experiencing harsh and unpredictable climatic conditions as a result of climate change (M = 3.89; SD = 0.90).

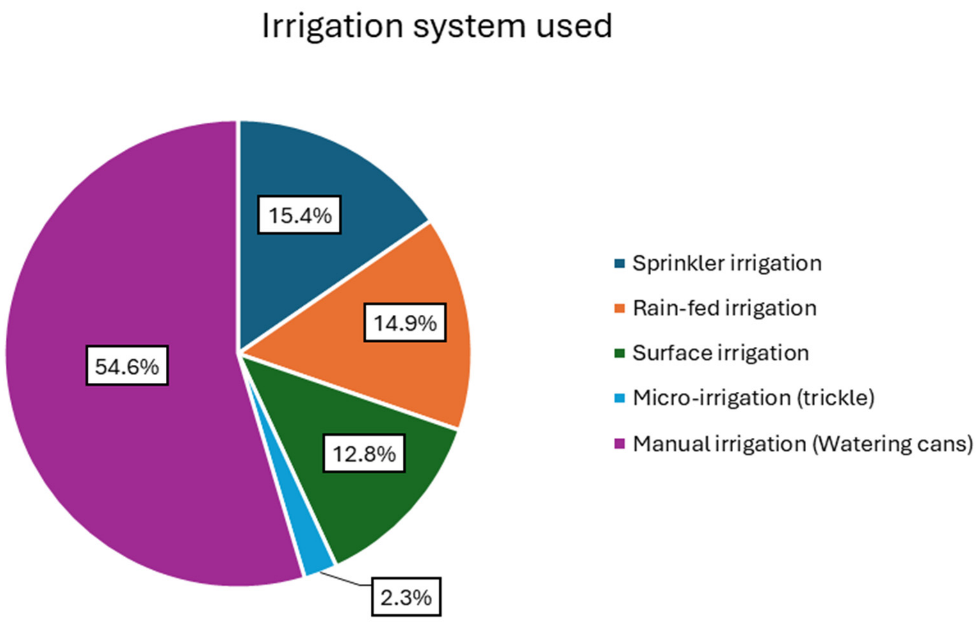

Figure 8. The distribution of irrigation systems among smallholder farmers.

Table 2. Barriers to redesigning production practices for WUE.

Challenges	N	Minimum	Maximum	Mean	Std. Deviation
I lack reliable water supply.	141	1.00	5.00	3.60	1.00
The soil on my farm has a poor water-holding capacity.	141	1.00	5.00	3.78	0.85
I do not have water efficient irrigation system (s).	141	1.00	5.00	3.91	0.71
I cannot irrigate as much as I would due to a lack of water storage system.	141	1.00	5.00	3.85	0.93
I do not have access to financial assistance.	141	1.00	5.00	4.09	0.85
My farm income is inconsistent seasonally due to unreliable market.	141	1.00	5.00	3.96	0.91
I do not have enough knowledge on irrigation water management.	141	1.00	5.00	4.00	0.84
Climate change effects such as droughts regularly affect my production output.	141	1.00	5.00	3.89	0.90

Table 3. The correlation of primary irrigation water source and the application of WUE approaches.

		Primary Irrigation Water Source	Application of WUE Approaches
Primary irrigation water source	Pearson Correlation	1	0.339 **
	Sig. (2-tailed)		0.000
	N	141	141
Application of WUE approaches	Pearson Correlation	0.339 **	1
	Sig. (2-tailed)	0.000	
	N	141	141

Note: ** Correlation is significant at the 0.01 level (two-tailed).

3.3. The Correlation of Primary Irrigation Water Source and the Applicarion of WUE Approaches

With regard to the correlation between the primary irrigation water source and the WUE approaches used by smallholder farmers, a moderate positive correlation ($r = 0.339$, $n = 141$, $p < 0.001$) was found, as presented in Table 3. This finding has substantial consequences for understanding the barriers farmers encounter when seeking to redesign their production practices. The modest positive correlation implies that, while there is a link between the primary irrigation water source utilized and the application of WUE approaches, the correlation is not strong.

The heatmap (Figure 9) below visually represents the hypothetical correlations between various water-use efficiency (WUE) practices and primary irrigation water sources. The color gradient and corresponding numeric values provide insights into the strength of the correlation, where darker blue shades signify stronger positive correlations and lighter shades represent weaker correlations. The numeric values in each cell range from 0 to 1, indicating the degree of association between each WUE practice and a specific irrigation water source.

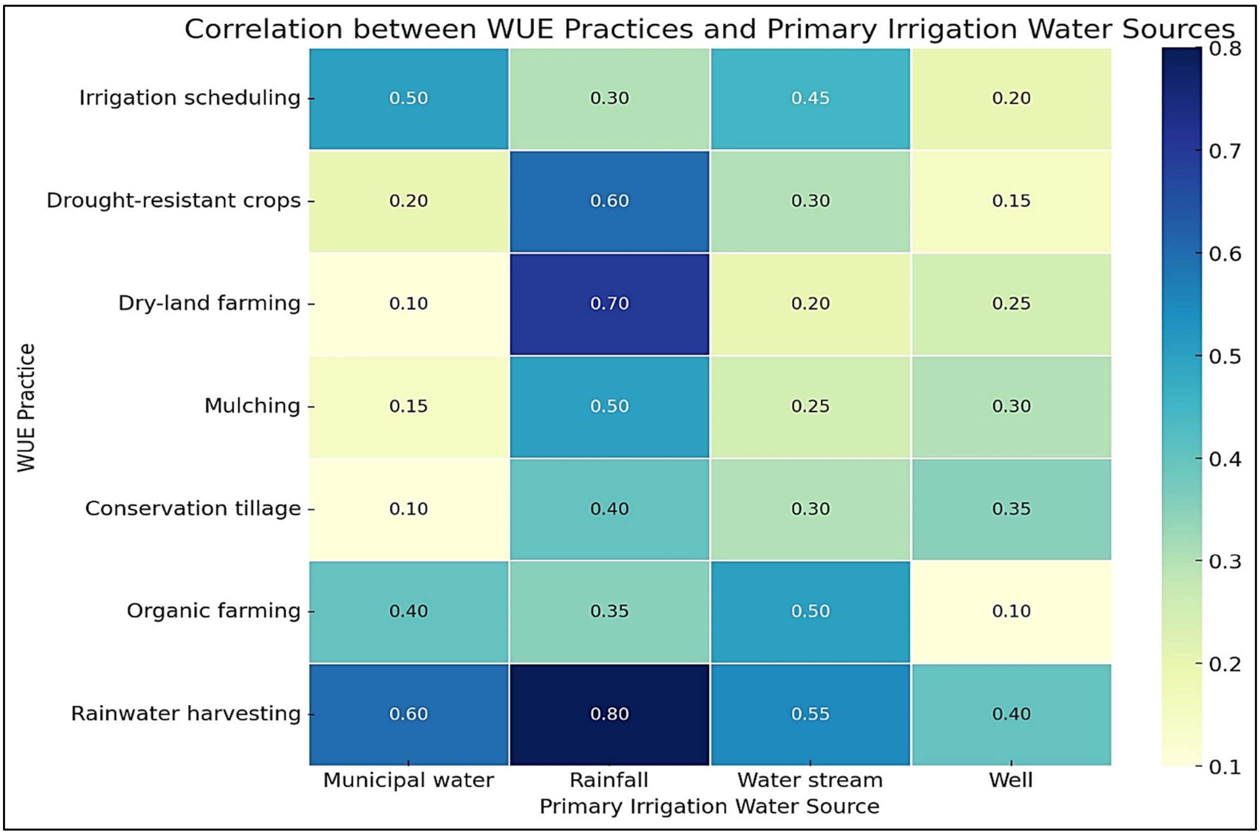

Figure 9. A heatmap on the correlation between primary irrigation water source and the application of WUE practices.

Rainwater harvesting demonstrates the strongest correlation with rainfall as a primary water source, which is expected given its reliance on precipitation as a direct source. Moderate correlations with municipal water and water streams suggest that these sources may supplement rainwater harvesting in varying seasonal conditions, allowing farmers to rely on stored rainwater as an alternative or complementary source.

Irrigation scheduling shows a moderate correlation with municipal water and water streams, which are typically more controlled and predictable sources. The use of irrigation scheduling may be more feasible and effective when water availability is steady, allowing farmers to plan water application efficiently. Organic farming exhibits a moderate correlation with several water sources such as municipal water, water streams, and rainfall. This relationship aligns with organic practices, which often emphasize sustainable and adaptable water use. Farmers practicing organic farming may draw on a combination of water sources to support crop growth and soil health.

Drought-resistant crops show a relatively strong correlation with rainfall. This association reflects the desirability of these crops for their ability to thrive in low-water environments, thus aligning with rain-dependent systems and reducing the need for supplemental irrigation. Dry-land farming is strongly correlated with rainfall, as it primarily relies on natural precipitation instead of artificial irrigation. This practice is well suited to environments where water access is limited or inconsistent.

4. Discussion

4.1. Socioeconomic Factors of Smallholder Farmers in the Study Area

As women make up most smallholder farmers, initiatives meant to improve WUE must consider the requirements and difficulties women experience. This might entail tackling problems like women's training programs, decision-making authority, and resource accessibility [29]. Furthermore, the population of elderly farmers raises the possibility of difficulties in implementing new procedures or technology that enhances WUE. There is a likelihood that older farmers are less motivated or equipped to alter traditional methods [8,14]. This emphasizes the necessity of providing elderly farmers with relevant and accessible targeted education and support programs.

The literacy rate is positive and reassuring as it indicates that many farmers may be able to comprehend and use more sophisticated WUE methods [30,31]. This higher level of access to formal education among smallholder farmers can be used in farmer-training programs to present sophisticated ideas, information, and methods. With respect to farming experience, most smallholder farmers have a great deal of agricultural expertise, which can work to their advantage because they may be better at comprehending and applying water-efficient techniques [32]. It also suggests, nevertheless, that any innovative approaches must complement existing ones or be an advancement over them [33].

As 84% of smallholder farmers earn their income from sources other than farming, this indicates the need for a diversified income stream. This could lead to increased financial stability and the opportunity to invest in more effective water-use practices [34,35]. The 16% who rely solely on smallholder farming as a source of income could be more susceptible to problems with water [36]. The WUE approaches used by smallholder farmers in the study area reflect their adaptability to water shortage and climate unpredictability. This shows a significant preference for techniques that catch and use available water effectively by the smallholder farmers [37].

Municipality-supplied water is the preferred source of irrigation water by smallholder farmers in the study area because of its reliability compared to rainfall [38]. This reliance emphasizes the necessity of managing these sources sustainably to guarantee their efficiency and availability over the long run [39,40]. Moreover, the other notable proportion that depends on rainfall underscores the crucial function of rainwater harvesting in enhancing water-use efficiency [41].

Smallholder farmers in the study area are heavily reliant on manual irrigation systems with little use of highly water-efficient micro-irrigation systems such as the drip irrigation system. The preference of smallholder farmers for manual irrigation systems is indicative of their limited access to or inability to buy modern irrigation technologies [42]. The low percentage of farmers that use micro-irrigation points to a lack of resources or expertise needed to put such effective systems in place [43].

4.2. Barriers in Redesigning Production Practices for Water-Use Efficiency

Most smallholder farmers primarily depend on rainfall to fulfill their irrigation water needs [44]. However, rainfall patterns are unpredictable in South Africa and can lead to smallholder farmers not being able to plan for their crops and manage their water resources efficiently [14]. Consequently, a lack of a reliable water supply is a common contributor to low yields and food insecurity [45]. To add to this, farmers constantly struggle with water availability, which makes it challenging to develop and carry out efficient irrigation schedules and strategies. This dependability issue underlines the need for better infrastructure to provide a continuous water supply. Additionally, the occurrence of soils with poor water-holding capacity suggests that the soils on these smallholder farms lack the ability to retain water effectively, leading to greater water requirements for crops. Therefore, irrigation must occur more often, placing additional strain on the already scarce water supplies and emphasizing the need for soil management techniques or improvements.

The notable lack of water-efficient irrigation systems suggests that smallholder farmers in the study area are likely wasting a lot of water by using ineffective techniques. Improving WUE requires the adoption of contemporary, effective irrigation technology, such as sprinkler or drip systems [46]. Furthermore, farmers are susceptible during dry seasons as they are unable to collect and store water during times of surplus due to a lack of water storage systems or facilities. Creating sufficient water storage capacity is essential to preserve a steady water supply and enhance water management in general [47].

The lack of access to finances by smallholder farmers in this study indicates that financial limitations also play a significant role in slowing down the adoption of sustainable agricultural practices such as WUE. This lack of access to finances means smallholder farmers are unable to make investments in WUE technology, infrastructure, and other essential inputs without the financial means and financing availability [48]. This problem is exacerbated by economic volatility brought on by unreliable markets, which makes it difficult for farmers to make long-term investments in sustainable agricultural practices [49]. This irregularity affects their capacity for risk-taking and financial planning [50], highlighting the necessity of dependable and easily accessible markets for agricultural goods to guarantee a steady flow of revenue and promote investment in environmentally friendly methods.

Another barrier to smallholder farmers' capacity to maximize water use is a lack of access to information regarding irrigation water management. This can lead smallholder farmers to use inefficient water management practices that will only exacerbate the effects brought on by water shortages. Thus, to teach farmers the best strategies for managing their water resources, training and extension services are essential [51]. In addition to lacking information on WUE practices, these difficulties are made worse by harsh and unpredictable weather patterns brought forth by climate change. To deal with these changes, farmers must implement more resilient farming techniques and technology [52], such as improved water management techniques.

4.3. The Correlation of Primary Irrigation Water Sources and the Applicarion of WUE Approaches

The study findings on the correlation between the application of WUE approaches and the primary irrigation water source suggests that variables other than the primary irrigation water source such as irrigation infrastructure, knowledge, and economic barriers may have a greater impact on farmers' decisions and abilities to apply WUE approaches [53]. In terms of practice, this result highlights how difficult it is to increase WUE in smallholder agriculture. Furthermore, the results implies that increasing irrigation water access on its own might not enhance WUE unless it is combined with supportive policies that tackle other important obstacles noted in research [53,54], like insufficient irrigation infrastructure, scarce financial resources, and a lack of awareness regarding efficient irrigation management.

Furthermore, the minor effect that irrigation water sources have on WUE methods emphasizes the necessity of integrated and comprehensive approaches to agricultural growth in these circumstances. A comprehensive approach should be considered when enhancing WUE among smallholder farmers. This approach should include infrastructure development to guarantee dependable access to water and storage facilities, financial support or incentives for investing in WUE technologies, and capacity-building through agricultural extension services to improve farmers' knowledge and skills in effective water management [55]. The modestly positive correlation highlights the complex nature of the barriers that smallholder farmers encounter in redesigning production practices for WUE, even while it offers some insight into the correlation between the primary irrigation water source and WUE approaches among them.

The correlations represented in the heatmap (Figure 9) provide insights into how different WUE practices align with specific irrigation water sources. This understanding is beneficial for stakeholders, including agricultural extension officers and policymakers, who seek to promote WUE strategies in various farming contexts. Farmers with access to more stable and controlled water sources such as municipal water may benefit from practices like irrigation scheduling, which enables them to allocate water resources at optimal times for crop needs [56]. Conversely, those relying on rainfall may prioritize rainwater harvesting or the use of drought-resistant crops, which are more compatible with variable or limited water availability [57]. Therefore, agricultural policy planners and/or extension officers can use such correlations to suggest WUE practices that are more compatible with available water sources, helping to optimize water use in different farming contexts.

4.4. Study Summary

The socioeconomic factors affecting smallholder farmers in the study area are closely connected to the barriers they encounter in redesigning their production practices for water-use efficiency (WUE) practices. Their ability to use water-efficient practices is influenced by socioeconomic variables such as age, gender, and their level of education. Although older and less adequately literate individuals may find it difficult to adopt more advanced techniques, many farmers rely on manual irrigation methods. Adoption of effective water-use techniques is hampered by a lack of knowledge regarding irrigation management, which further strengthens the dependence on traditional practices.

Another major factor impeding the redesign of production practices for WUE is economic restrictions [8,58]. Due to their reliance on non-farm income, many farmers may be less inclined to engage in agricultural developments focused on promoting WUE. Furthermore, farmers find it challenging to access essential infrastructure, such as efficient irrigation systems and water storage facilities, due to limited access to finances and/or credit. Farmers are deterred from committing to long-term WUE resolutions by this financial volatility, which is exacerbated by erratic markets and climatic circumstances [59]. Improving farmers' access to information, funding, and the infrastructure required to implement more effective techniques will be necessary to address these issues.

4.5. Study Limitations

The sampling method (simple random sampling) used in this study can result in an under-representative sample as differences in the sample might have been overlooked by, for example, focusing more on crop and mixed farmers rather than livestock farmers. The data collection tool (structured questionnaire) can be rigid in a sense that smallholder farmers are only limited to choosing the options provided to them by the researchers.

Language barriers between the English-drafted questionnaire and the Siswati-speaking respondents in the study resulted in Likert-scale compression. This problem occurs when respondents become unclear or confused because of direct translations of the Likert-scale questions that may not fully convey the intended meanings. The English language skill of the respondents may vary, which could have an impact on how well they comprehend the scale and how they respond. The reliability and validity of data collected using Likert scales can be improved by conducting cognitive interviews and rigorous pilot studies, making sure that translations are accurate and culturally appropriate, and clearly providing instructions for respondents.

5. Conclusions

The barriers highlighted in the study must be resolved in smallholder production practices to redesign smallholder production practices for WUE. These include the financial barriers that keep farmers from adopting sustainable practices, the restricted availability of contemporary irrigation systems (micro-irrigation systems) and equipment (soil moisture sensors), and the lack of training and understanding among farmers. Implementing water-efficient technologies is also made more difficult by socioeconomic issues such as poor access to information on WUE. A holistic approach including investment in irrigation infrastructure, targeted education initiatives by agricultural extension agents, and stakeholder participation is needed to overcome these barriers. To address the barriers limiting the adoption of water-use efficiency (WUE) practices among smallholder farmers, the following policy interventions are recommended:

- Enhancing access to affordable credit and financial instruments is essential, enabling farmers to invest in advanced irrigation systems and water storage infrastructure.
- Improving farmer education and capacity-building initiatives, particularly in irrigation management, is critical. These programs should target older and less educated farmers to facilitate the adoption of more sophisticated WUE practices.
- Policy efforts must also prioritize investment in water infrastructure, ensuring equitable access to reliable water sources and promoting the implementation of efficient irrigation technologies, such as drip or micro-irrigation systems.
- Policies should promote climate-resilient agricultural practices, including the cultivation of drought-tolerant crops and the adoption of soil water retention techniques, to help farmers adapt to the challenges posed by climate variability.
- To reduce financial instability, improving market access and stability through the strengthening of local agricultural markets and farmer cooperatives is necessary, as this would encourage greater investment in sustainable WUE practices.
- In conclusion, gender-sensitive policy interventions that provide targeted support to female farmers are imperative to ensure equitable resource allocation and empowerment.

Implementing these policy recommendations would create a conducive environment for smallholder farmers to overcome socioeconomic barriers and enhance the efficiency of water use in their agricultural systems.

Author Contributions: Conceptualization, M.T.M. and I.A.A.; methodology, N.S.M.; software, M.T.M.; validation, L.I.M., M.Z.S. and V.N.T.; formal analysis, M.T.M. and M.Z.S.; investigation, M.T.M., V.N.T. and I.A.A.; resources, N.S.M.; data curation, M.T.M.; writing—original draft preparation, L.I.M., V.N.T., N.S.M. and M.T.M.; writing—review and editing, M.T.M., M.Z.S. and I.A.A.; visualization, M.T.M.; supervision, I.A.A.; project administration, I.A.A. and M.Z.S.; funding acquisition, M.Z.S. and I.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Agricultural Research Council of South Africa (ARC) through the Agriculture Sector Education and Training Authority (AgriSETA), and the APC was funded by the University of Mpumalanga (UMP).

Data Availability Statement: Data will be made available upon request.

Acknowledgments: The University of Mpumalanga is acknowledged for granting the ethical clearance (UMP/Morepje/201503045/MAGR/2023) for this study. Also, the Agricultural Research Council of South Africa (ARC) and AgriSETA are thanked for funding this study. Furthermore, the authors give gratitude to the South African Society for Agricultural Extension (SASAE) for allowing the study to be presented at their 57th Annual conference on the 27 August 2024.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Rosa, L.; Chiarelli, D.D.; Rulli, M.C.; Dell 'Angelo, J.; D'Odorico, P. Global agricultural economic water scarcity. *Sci. Adv.* **2020**, *6*, eaaz6031. [CrossRef] [PubMed]
2. Agholor, A.I.; Nkosi, M. Sustainable water conservation practices and challenges among smallholder farmers in Enyibe Ermelo Mpumalanga Province, South Africa. *J. Agric. Ext.* **2020**, *24*, 112–123. [CrossRef]
3. Ogundeji, A.A. Adaptation to climate change and impact on smallholder farmers' food security in South Africa. *Agriculture* **2022**, *12*, 589. [CrossRef]
4. Mbuli, C.S.; Fonjong, L.N.; Fletcher, A.J. Climate change and small farmers' vulnerability to food insecurity in Cameroon. *Sustainability* **2021**, *13*, 1523. [CrossRef]

5. Rapholo, M.T.; Diko Makia, L. Are smallholder farmers' perceptions of climate variability supported by climatological evidence? Case study of a semi-arid region in South Africa. *Int. J. Clim. Chang. Strat. Manag.* **2020**, *12*, 571–585. [CrossRef]
6. Matos, S.; Viardot, E.; Sovacool, B.K.; Geels, F.W.; Xiong, Y. Innovation and climate change: A review and introduction to the special issue. *Technovation* **2022**, *117*, 102612. [CrossRef]
7. Haileslassie, A.; Agide, Z.; Erkossa, T.; Hoekstra, D.; Schmitter, P.S.; Langan, S.J. *On-Farm Smallholder Irrigation Performance in Ethiopia: From Water Use Efficiency to Equity and Sustainability*; International Livestock Research Institute: Nairobi, Kenya, 2016; pp. 1–33.
8. Morepje, M.T. Redesigning Production Systems for Water-Use Efficiency Amongst Smallholder Farmers at Numbi, South Africa. Master's Thesis, University of Mpumalanga, Mbombela, South Africa, 2024. Available online: https://openscholar.ump.ac.za/handle/20.500.12714/803 (accessed on 21 September 2024).
9. Mohammedshum, A.A.; Mannaerts, C.M.; Maathuis, B.H.; Teka, D. Integrating socioeconomic biophysical and institutional factors for evaluating small-scale irrigation schemes in Northern Ethiopia. *Sustainability* **2023**, *15*, 1704. [CrossRef]
10. Antwi-Agyei, P.; Stringer, L.C. Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. *Clim. Risk Manag.* **2021**, *32*, 100304. [CrossRef]
11. Nhamo, L. Chapter 8—Advances in water research: Enhancing sustainable water use in irrigated agriculture in South Africa. *Sustain. Dev.* **2023**, *19*, 233–248. [CrossRef]
12. Branca, G.; Cacchiarelli, L.; Haug, R.; Sorrentino, A. Promoting sustainable change of smallholders' agriculture in Africa: Policy and institutional implications from a socio-economic cross-country comparative analysis. *J. Clean. Prod.* **2022**, *11*, 478. [CrossRef]
13. DEA (DWS). National Water and Sanitation Master Plan. Department of Water and Sanitation, South Africa. 2019. Available online: https://www.dws.gov.za/National%20Water%20and%20Sanitation%20Master%20Plan/ (accessed on 16 September 2024).
14. Morepje, M.T.; Agholor, I.A.; Sithole, M.Z.; Mgwenya, L.I.; Msweli, N.S.; Thabane, V.N. An Analysis of the Acceptance of Water Management Systems among Smallholder Farmers in Numbi, Mpumalanga Province, South Africa. *Sustainability* **2024**, *16*, 1952. [CrossRef]
15. Kapari, M.; Hlophe-Ginindza, S.; Luxon, N.; Mpandeli, S. Contribution of smallholder farmers to food security and opportunities for resilient farming systems. *J. Front. Sustain. Food Syst.* **2023**, *7*, 11. [CrossRef]
16. Kamara, A.; Abdul, R.; Edward, R.; Richard, C. The relevance of smallholder farming to African Agricultural Growth and Development. *Afr. J. Front.* **2019**, *19*, 14043–14065. [CrossRef]
17. Wakweya, R.B. Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security. *J. Agric. Food Res.* **2023**, *14*, 100698. [CrossRef]
18. Mwale, M.; Sibuyi, S.K.; Downsborough, L.; Zuwarimwe, J. Developing resilient small-scale farmers against water scarcity in rural-based crop production farms, South Africa. *Agriculture* **2021**, *23*, 34–52. [CrossRef]
19. Alharbi, S.; Abrar, F.; Ahmed, A.; Al-Dakhil, M. Agricultural and Technology-based strategies to improve water-use efficiency in Arid and Semiarid areas. *Water* **2024**, *16*, 1842. [CrossRef]
20. Evans, R.; Sadler, J. Methods and technologies to improve efficiency of water use. *J. Water Resour. Res.* **2008**, *44*, 674. [CrossRef]
21. Ingrao, C.; Rossana, S.; Giovanni, L.; Huisingh, D. Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. *Heliyon* **2023**, *9*, e18507. [CrossRef]
22. Department of Water Affairs (DWA). National Water Policy of South Africa. Available online: https://www.dws.gov.za/documents/Other/Strategic%20Plan/NWRS2-Final-email-version.pdf (accessed on 12 July 2024).
23. Msweli, N.S.; Agholor, I.A.; Sithole, M.Z.; Morepje, M.T.; Thabane, V.N.; Mgwenya, L.; Msweli, N.S. The Determinants and Acceptance of Climate Smart Agriculture Practices in South Africa. *Afr. J. Food Agric. Nut. Dev.* **2024**, *24*, 24591–24610. [CrossRef]
24. Food and Agriculture Organization of the United Nations (FAO). The State of Agricultural Commodity Markets. Rome, Italy. 2022. Available online: https://www.fao.org/publications/home/fao-flagship-publications/the-state-of-agricultural-commodity-markets/en (accessed on 22 October 2024).
25. Bouis, H.E.; Saltzman, A. Improving nutrition through bio-fortification: A review of evidence from Harvest-Plus, 2003 through 2016. *Glob. Food Sec.* **2018**, *12*, 49–58. [CrossRef]
26. Nkiaka, E.; Bryant, R.G.; Okumah, M.; Gomo, F.F. Water security in sub-Saharan Africa: Understanding the status of sustainable development goal 6. *Wiley Interdiscip. Rev. Water* **2021**, *8*, e1552. [CrossRef]
27. StatsSA. My Settlement. 2011. Available online: https://www.statssa.gov.za/?page_id=4286&id=11670 (accessed on 6 July 2024).
28. Bukhari, S.A. The impact of a global Englishes course on teachers' attitudes towards teaching English as a global language. *Int. J. Engl. Lang. Teach.* **2023**, *11*, 25–42. [CrossRef]
29. Assan, E.; Suvedi, M.; Olabisi, L.S.; Bansah, K.J. Climate change perceptions and challenges to adaptation among smallholder farmers in semi-arid Ghana: A gender analysis. *J. Arid Environ.* **2020**, *182*, 104247. [CrossRef]
30. Mallareddy, M.; Thirumalaikumar, R.; Balasubramanian, P.; Naseeruddin, R.; Nithya, N.; Mariadoss, A.; Eazhilkrishna, N.; Choudhary, A.K.; Deiveegan, M.; Subramanian, E.; et al. Maximizing water use efficiency in rice farming: A comprehensive review of innovative irrigation management technologies. *Water* **2023**, *15*, 1802. [CrossRef]

31. Alant, B.P.; Bakare, O.O. A case study of the relationship between smallholder farmers' ICT literacy levels and demographic data wrt their use and adoption of ICT for weather forecasting. *Heliyon* **2021**, *7*, e06403. [CrossRef]
32. Thinda, K.T.; Ogundeji, A.A.; Belle, J.A.; Ojo, T.O. Understanding the adoption of climate change adaptation strategies among smallholder farmers: Evidence from land reform beneficiaries in South Africa. *Land Use Policy* **2020**, *99*, 104858. [CrossRef]
33. Atube, F.; Malinga, G.M.; Nyeko, M.; Okello, D.M.; Alarakol, S.P.; Okello-Uma, I. Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agric. Food Secur.* **2021**, *10*, 1–14. [CrossRef]
34. Sapbamrer, R.; Thammachai, A. A systematic review of factors influencing farmers' adoption of organic farming. *Sustainability* **2021**, *13*, 3842. [CrossRef]
35. Danso-Abbeam, G.; Dagunga, G.; Ehiakpor, D.S. Rural non-farm income diversification: Implications on smallholder farmers' welfare and agricultural technology adoption in Ghana. *Heliyon* **2020**, *6*, e05393. [CrossRef]
36. Agbenyo, W.; Jiang, Y.; Jia, X.; Wang, J.; Ntim-Amo, G.; Dunya, R.; Siaw, A.; Asare, I.; Twumasi, M.A. Does the adoption of climate-smart agricultural practices impact farmers' income? Evidence from Ghana. *Int. J. Environ. Res. Public Health* **2022**, *19*, 3804. [CrossRef]
37. Mwangi, R.M.; Kimemia, G.M.; Kuria, J.M. Effect of irrigation scheduling and rainwater harvesting on maize (Zea mays L.) productivity and soil moisture in semi-arid areas of Kenya. *J. Afr. Earth Sci.* **2017**, *124*, 232–243.
38. Paudel, K.P.; Pandit, M.; Hinson, R. Irrigation water sources and irrigation application methods used by US plant nursery producers. *Water Resour. Res.* **2016**, *52*, 698–712. [CrossRef]
39. Mabuza, M.; Ndoro, J.T. Borich's needs model analysis of smallholder farmers' competence in irrigation water management: Case study of Nkomazi local municipality, Mpumalanga province in South Africa. *Sustainability* **2023**, *15*, 4935. [CrossRef]
40. 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 SA* **2022**, *48*, 97–109. [CrossRef]
41. Abdullah, A.H.; Almasraf, S.A. Assessment Improving of Rainwater Retention on Crop Yield and Crop Water Use Efficiency for Winter Wheat. *J. Eng.* **2020**, *26*, 46–54. [CrossRef]
42. Van De Zande, G.D.; Amrose, S.; Donlon, E.; Shamshery, P.; Winter V, A.G. Identifying opportunities for irrigation systems to meet the specific needs of farmers in East Africa. *Water* **2024**, *16*, 75. [CrossRef]
43. Mitku, D.T.; Adamite, T.F.; Tefera, A.H. Verification and Demonstration of Low-Cost and Appropriate Micro-Irrigation System for Crop Production Under Smallholder Farmers Condition in Pawe District of Metekel Zone. *Int. J. Adv. Res. Biol. Sci.* **2022**, *9*, 198–206.
44. Dessale, M. Determinants and food security impacts of small-scale irrigation in Ethiopia. *J. Bus. Econ.* **2020**, *11*, 6. [CrossRef]
45. Mugejo, K.; Ncube, B. Determinants of water security in smallholder farming systems in South Africa: A review. *Fundam. Appl. Agric.* **2022**, *7*, 235–249. [CrossRef]
46. Patel, A.; Kushwaha, N.L.; Rajput, J.; Gautam, P.V. Advances in Micro-Irrigation Practices for Improving Water Use Efficiency in Dryland Agriculture. In *Enhancing Resilience of Dryland Agriculture Under Changing Climate: Interdisciplinary and Convergence Approaches*; Springer Nature: Singapore, 2023; pp. 157–176. [CrossRef]
47. Zerssa, G.; Feyssa, D.; Kim, D.G.; Eichler-Löbermann, B. Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. *Agriculture* **2021**, *11*, 192. [CrossRef]
48. Yu, L.; Gao, X.; Zhao, X. Global synthesis of the impact of droughts on crops' water-use efficiency (WUE): Towards both high WUE and productivity. *Agric. Syst.* **2020**, *177*, 102723. [CrossRef]
49. Usman, M.A.; Callo-Concha, D. Does market access improve dietary diversity and food security? Evidence from Southwestern Ethiopian smallholder coffee producers. *Agric. Food Econ.* **2021**, *9*, 18. [CrossRef]
50. Balana, B.B.; Oyeyemi, M.A. Agricultural credit constraints in smallholder farming in developing countries: Evidence from Nigeria. *World Dev. Sustain.* **2022**, *1*, 100012. [CrossRef]
51. Liu, Y.; Song, W. Modelling crop yield, water consumption, and water use efficiency for sustainable agroecosystem management. *J. Clean. Prod.* **2020**, *253*, 119940. [CrossRef]
52. Kom, Z.; Nethengwe, N.S.; Mpandeli, N.S.; Chikoore, H. Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. *GeoJournal* **2022**, *87*, 677–700. [CrossRef]
53. De Witt, M.; De Clercq, W.P.; Velazquez, F.J.B.; Altobelli, F.; Marta, A.D. An in-depth evaluation of personal barriers to technology adoption in irrigated agriculture in South Africa. *Outlook Agric.* **2021**, *50*, 259–268. [CrossRef]
54. Durga, N.; Schmitter, P.; Ringler, C.; Mishra, S.; Magombeyi, M.S.; Ofosu, A.; Pavelic, P.; Hagos, F.; Melaku, D.; Verma, S.; et al. Barriers to the uptake of solar-powered irrigation by smallholder farmers in sub-Saharan Africa: A review. *Energy Strat. Rev.* **2024**, *51*, 101294. [CrossRef]
55. Singh, S. Farmers' Perception of Climate Change and Adaptation Decisions: A Micro-Level Evidence from Bundelkhand Region, India. *Ecol. Indic.* **2020**, *116*, 106475. [CrossRef]
56. Guo, D.; Olesen, J.E.; Manevski, K.; Ma, X. Optimizing irrigation schedule in a large agricultural region under different hydrologic scenarios. *Agric. Water Manag.* **2021**, *245*, 106575. [CrossRef]
57. Velasco-Muñoz, J.F.; Aznar-Sánchez, J.A.; Batlles-delaFuente, A.; Fidelibus, M.D. Rainwater harvesting for agricultural irrigation: An analysis of global research. *Water* **2019**, *11*, 1320. [CrossRef]

58. Morepje, M.T.; Sithole, M.Z.; Msweli, N.S.; Agholor, A.I. The Influence of E-Commerce Platforms on Sustainable Agriculture Practices among Smallholder Farmers in Sub-Saharan Africa. *Sustainability* **2024**, *16*, 6496. [CrossRef]
59. Sithole, M.Z.; Agholor, I.A.; Msweli, N.S.; Morepje, M.T. Towards Sustainable Agriculture: The Opportunities and Challenges of Artificial Intelligence in Agricultural Advisory Services. *Proc. NEMISA Digit.* **2024**, *6*, 1–12. [CrossRef]