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An Analysis of the Acceptance of Water Management Systems among Smallholder Farmers in Numbi, Mpumalanga Province, South Africa

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Abstract: The study investigated the relationship between smallholder farmers' socioeconomic characteristics and their choice to implement formal water management systems in the context of agricultural output in Numbi, Mpumalanga Province, South Africa. Numbi is a farming community situated in the Mbombela Local Municipality within the Ehlanzeni District Municipality of Mpumalanga Province. The study featured 141 smallholder farmers who were chosen using a straightforward random sampling method. A systematic and structured questionnaire was used to collect the data, and binary logistic regression was used to analyze the acceptability of formal water management systems among smallholder farmers. The results revealed statistically significant relationships with gender (p = 0.025), age (p = 0.186), educational level (p = 0.087), farm size (p = 0.151), household size (p = 0.041), and the use of alternative irrigation (p < 0.001). These findings underscore the importance of socioeconomic factors in influencing smallholder farmers' openness to adopting formal water management systems. The study, therefore, recommends that policymakers, extension agents, and other stakeholders should prioritize farmer socioeconomic factors when advocating for the acceptance of formal water management systems. Hence, water-use efficiency, increased crop yields, and livelihood security will be eminent, thus improving the overall farmer quality of life in the study area.

Keywords: agricultural productivity; water conservation; innovation adoption; water scarcity

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1. Introduction

In the context of South Africa's smallholder farming, formal water management systems refer to the institutionalized and regulated systems for managing water resources [1]. This includes water resource planning, allocation, monitoring, and regulation, all of which are typically carried out by government agencies or other organizations that are formally recognized and empowered to manage water resources [2]. Smallholder farmers in South Africa often have a deep mistrust of formal institutions, as mentioned in the study by [1,3], and there are many barriers to their acceptance of formal water management systems [4]. These barriers include issues of cost, lack of trust, and a lack of understanding of the benefits of formal water management systems [3]. However, there are also opportunities to address these barriers and increase the likelihood of acceptance such as socioeconomic issues of smallholder farmers. Hence, water use efficiency (WUE) approaches, which aim to maximize the benefits derived from irrigation water while minimizing its use, can be a key component of smallholder farmers' participation in formal water management systems. These approaches can help farmers to make the most of their limited water resources, while also ensuring that water is used in a sustainable and efficient manner. This is particularly important in the context of climate change and growing water scarcity.

In addition, water scarcity is a major problem for smallholder farmers in South Africa, and has an enormous impact on their livelihoods and agricultural methods [5]. Rain-fed agriculture is a major source of income for many smallholder farmers in South Africa [6,7]. Their susceptibility to variations in rainfall patterns is heightened by their restricted access to irrigation facilities. As a result, the reliance on rain-fed agriculture makes smallholder farmers more vulnerable to the negative effects of climate change, such as erratic rainfall patterns and protracted droughts [8–10]. Smallholder farmers may compete with other sectors, including industry and urban areas, for limited water supplies in locations where such resources are rare [11]. The problems confronting smallholder farmers might be made worse by this rivalry, which could result in less water being available for agriculture.

Also, their capacity to maximize water usage is hampered by the lack of contemporary irrigation methods and water management techniques [12], which renders them more vulnerable to the detrimental impacts of water shortages. Smallholder farmers are frequently compelled by water scarcity to rethink their crop selection [13]. While some may diversify their agricultural operations to include livestock or other less water-dependent sources of income, others may switch to crops that are resistant to drought or require less water [8]. Additionally, smallholder farmers are more vulnerable financially owing to water shortages, which cause reduced yields and crop failures that affect their income and food security, resulting in a poverty cycle that is difficult to escape without sufficient assistance and resources [14].

To combat water scarcity and assist smallholder farmers, the South African government has launched several measures. These involve the creation of water infrastructure, the advocacy of environmentally friendly methods of managing water resources, and financial support initiatives through Agricultural Extension Services [15]. Some smallholder farmers participate in community-based programs to address the scarcity of water [16]. This is an essential platform for farmers to exchange information and expertise, work together to conserve water, and share water resources. Furthermore, this has been viewed as one of the most effective and efficient ways of serving the community through agricultural extension programs in the country. Smallholder farmers in South Africa stand to gain a lot by adopting formal water management systems, such as enhanced agricultural output, sustainable resource use, and improved farm water use efficiency [17,18].

However, several socioeconomic issues may make it more difficult for smallholder farmers to adopt these methods. Farmers' socioeconomic issues call for a comprehensive strategy that includes targeted financial assistance, educational initiatives, better information access (including rural information dissemination facilities), and the establishment and implementation of laws and policies that are beneficial, especially to smallholder farmers. To move beyond these obstacles and encourage South African smallholder farmers to adopt formal water management systems in a sustainable manner, cooperation between local communities, nongovernmental organizations, and governments is crucial. The focus of the study is to shed light on the socioeconomic variables that affect farmers' choices about water management techniques. This information can help policymakers develop more sustainable and inclusive practices. Last, but not least, the innovation lies in bridging the knowledge gap between research and practical application, which may result in workable ways to enhance water availability and utilization in farming environments.

1.1. Theoretical Framework

Albert Bandura's social learning theory (the AB theory) [19] is frequently used to explain the connection between socioeconomic conditions and the acceptance of new inventions or technologies [20], and it serves as the foundation for this investigation. According to the AB theory on social learning, people pick up new skills by watching and copying the actions of others [21]. This indicates that when it comes to embracing new technologies, people are more inclined to do so if they observe others in their social circle doing the same. People from low-income backgrounds, who might have fewer resources and less knowledge about adoption, should be aware of this [22]. They observe others while saving on investment costs, observing whether is it a worthwhile risk to take or not. According to the AB social learning theory, individuals from lower socioeconomic backgrounds may be more likely to adopt new technology if they have more access to information and good role models [23].

Understanding the link between the AB social learning theory and adoption requires an understanding of its four guiding principles [24] which are self-efficacy, mediating mechanisms, vicarious reinforcement, and observational learning. Vicarious reinforcement is the process of learning by seeing the results of other people's activity, whereas observational learning is the process of learning by watching and copying the actions of others [25,26]. On the contrary, self-efficacy is the conviction that one can carry out a certain task or conduct, and mediating processes denote how memory and motivation affect one's capacity to replicate taught behaviors [25,26].

From this theory it can be concluded that farmers are more inclined to adopt new technologies if they observe other farmers utilizing and profiting from the new technology [27], as this is referred to as social influence or social proof. In addition, the notion implies that before attempting to use new technologies, farmers should have faith in the information source. Finally, according to the notion of social learning, farmers must possess the necessary abilities and knowledge to effectively utilize new technologies [28]. Farmers are unlikely to use technology if it is very complicated or demands specialized knowledge. Therefore, for new technology to be adopted at a faster pace, it must be simple to use or apply, backed by industry professionals, and effectively promoted among farmers in their social networks.

1.2. Problem Statement

In South Africa, water scarcity brought on by more intense weather patterns attributed to climate change presents significant challenges for smallholder farmers [28]. These challenges are exacerbated by the dependence on informal water management systems, which have been shown to be unreliable and ineffective in supplying the necessary amount of water for mitigating the effects of climate change, such as prolonged droughts and high heat [29–31]. Prolonged droughts, prolonged water shortages, and intense heat are some of the resultant impacts that lead to decreased agricultural yields, increased poverty and food insecurity, and economic loss [32]. Implementing formal water management systems is seen as a workable alternative, as enhanced potential is acknowledged. Moreover, crop yields are increased by these systems as they provide a more dependable and effective irrigation water source [33].

Formal water management systems are also helpful in lowering water waste, advancing equitable water distribution, strengthening food security, and building resilience to climate change [34]. The burden of irrigation water management among smallholder farmers can possibly be lifted by the adoption of formal water management systems. This includes microirrigation systems, rainwater harvesting, community-based irrigation systems, and the use of ponds, wells, and boreholes [34]. However, the adoption rate has been significantly low due to many contributing factors, such as a lack of access to information and financial muscle.

The determinants of the adoption of formal water management systems among smallholder farmers are not well established. Hence, this study aimed to assess the socioeconomic factors influencing the adoption of formal water management systems among smallholder farmers. The study will benefit smallholder farmers, policymakers, and the general public by unveiling the underpinning factors influencing the adoption of readily available formal water management systems. This will aid policymakers in making informed decisions about farmer development policies, strategies, and programs, especially in South Africa.

1.3. Study Aim

The aim of this research was to examine the socioeconomic factors influencing smallholder farmers' implementation of water management systems.

2. Literature Review

For smallholder farmers in South Africa, formal water management techniques like rainwater collection and conservation tillage may greatly boost crop yields and water productivity [35]. These systems can stabilize the supply of water for both home and agricultural usage, which makes them especially crucial in water-scarce areas [36]. If extensively implemented, rainwater management strategies might boost crop and livestock yields as well as smallholder agriculture's profitability [37]. The introduction of water price and enhancements to the water rights system, however, might further increase the efficiency of small-scale irrigation, as the economic viability of these systems remains an issue [38].

The significance of farmers' attitudes towards water conservation, perceptions of a lack of water, and availability of village-based information and incentives were also emphasized by [39,40] in relation to their adoption of microirrigation systems and participation in water user groups. Ref. [41] highlighted the necessity of a change in the agricultural community's identities, normative behavioral attitudes, and social norms in order to support water pollution mitigation practices. Ref. [42] noted impediments to small-scale dairy producers' ability to provide drinking water for their cows, including infrastructure, security, education and training, and accessibility to water. The combined findings of this research highlight the intricate interactions of material, social, and human elements that influence smallholder farmers' perceptions of and actions related to formal water management systems.

The adoption of formal water management systems by smallholder farmers has been found to be successful in case studies when a mix of internal and external factors was present [43,44]. Ref. [45] highlights the necessity of sustained outside assistance, as well as financial, technical, and administrative guidance and community traits like strong leadership, group initiative, and institutional openness. Ref. [46] emphasizes how labor input is impacted by water prices, where lower costs result in higher irrigation rates and shorter labor durations. Another study emphasizes the importance of land use, farm size, and social capital in the adoption of water conservation techniques [47]. Significantly, Ref. [40] highlights the implication of farmers' attitudes towards water conservation, perceptions of a lack of water, village-based information, and incentives in influencing their adoption of microirrigation systems and involvement in water user groups.

In Sub-Saharan Africa, smallholder farmers encounter a variety of obstacles when attempting to adopt conventional water management methods. The disparity in access to water management methods is emphasized in [48], with women and farmers with limited resources facing specific disadvantages. Labor shortages, low market integration, high investment costs, a dearth of financial services, and insufficient information services all exacerbate this. Ref. [49] highlights even further how only wealthy farmers have access to water lifting technology because of their poorly constructed supply networks, lack of funding, high maintenance and operating expenses, and significant output price risks. Ref. [36] emphasizes the significance of land management techniques and rainfall distribution, especially in regions with limited water resources, whereas [50] supports small-scale farmer-managed irrigation, stressing the need to consider the intricacies of land and water management as well as social, political, and economic transformation.

3. Materials and Methods

3.1. Study Site

The study was carried out in Numbi as shown in Figure 1 below, which is a rural community situated near the Numbi Gate and Kruger National Park entrance and forms part of communities under the Mbombela Local Municipality in the Mpumalanga province of South Africa. The geographical coordinates of the rural community are 25°0739.8 S and 31°09′ 44. Data from [51] show that the size of the rural community is 4.57 square kilometers, comprising 7696 people and 1932 households. Furthermore, the dominant racial group is Africans, who make up 99 percent of the community, and 94 percent are of the Swati tribe [51]. The main economic activities are farming and tourism, with most of the households having backyard gardens consisting of seasonal crops, subtropical fruit trees, and nuts such as macadamia.

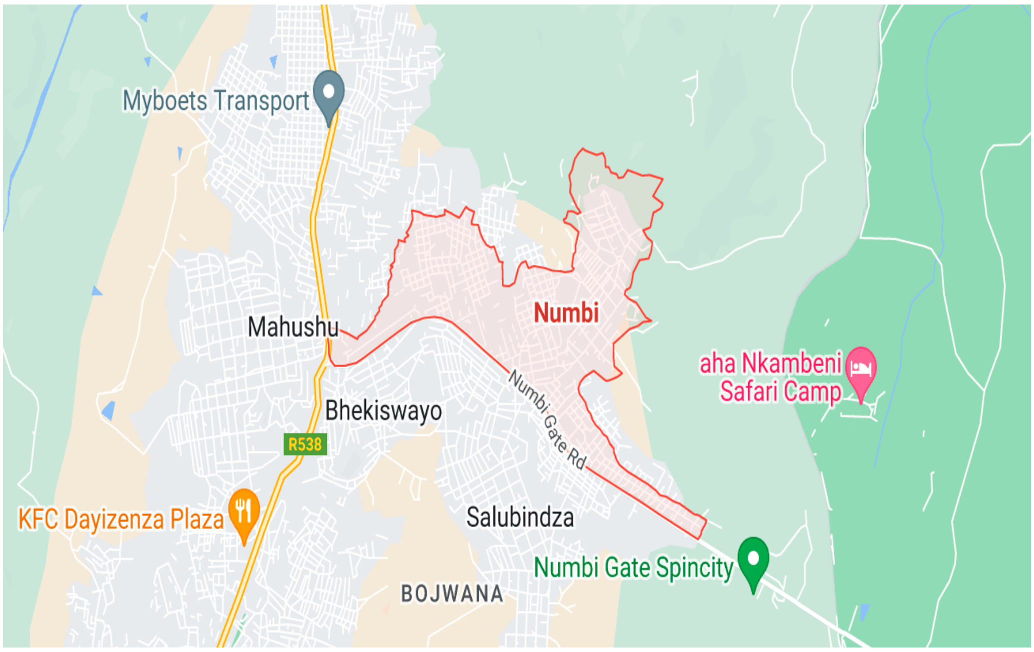

Figure 1. A map of Numbi, Mbombela Local Municipality.

3.2. Sampling Method and Sample Size

A simple random sampling method was employed to select participants from the entire population of farmers, estimated to be around 217, out of which 67 are registered with the local Department of Agriculture and an estimated 150 are not registered. The sample size for this study consisted of 141 respondents, determined using Taro Yamane's formula for sample size calculation, with a margin of error of 0.05 and a confidence interval of 95%. The equation is as follows:

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

$$n = \frac{N}{1+Ne^2}$$
$$n = \frac{217}{1 + 217(0.05)^2} \quad (1)$$
$$n = 141\ farmers$$

3.3. Study Design and Data Collection

The study followed a data-based research design, specifically employing a survey approach. A survey questionnaire was used to gather information from participants included in the study sample. The survey data focused on participants' viewpoints regarding the acceptance of formal water management systems.

To collect the primary data, a structured questionnaire was employed. The questionnaire was unbiased, clear, and relevant to the research objective. Enumerators were trained and all had exposure to a tertiary education level. The training included the protocols of data collection, how to implement the survey questionnaire effectively, and ethical consideration. Before the actual data collection, a pilot study was conducted using 20 random respondents, to identify issues or ambiguities in the questionnaires. Based on the pilot study, few revisions were made to give clarity and make sure that the answers of the respondents are reflected accurately. This step improved the reliability of our method of data collection.

3.4. Method of Data Analysis

The data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 28. To achieve the research objective and address the study aim, two methods were used: binary logistic regression and descriptive statistics. The binary logistic regression was used to assess the correlation between the acceptance of formal water management systems and the socioeconomic factors of farmers. The descriptive statistics were used to analyze the socioeconomic structure of the study sample by looking at the disparities among the farmers sampled in the study area.

3.5. The Model Adopted for the Study

The binary logistic model provides the benefit of analyzing the relationship between factors influencing smallholder farmers' innovation acceptance decisions and the rate of technology adoption [52]. Additionally, regression models are used to assist in estimating the probability of events based on the collective function of variables speculated to affect an outcome [53]. The distribution of predictor variables (X) is not assumed; however, these variables can be either discrete or continuous. The study investigated the connection between the demographic characteristics of smallholder farmers and their acceptance of formal water management systems in the study area. Thus, logistic regression is believed to be the optimal method when there is a combination of numerical and categorical data. The independent variables are hypothesized to influence the acceptance behavior, and the operational description, as well as the expected effect on the acceptance of formal water management systems by smallholder farmers at the study area, are contained in Appendix A of the manuscript. Indicated below is the approach employed to identify acceptance behavior:

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

where

Y = Intention to accept formal water management systems.
$X_1 - X_{11}$ = Independent variables demarcated as follows:
X_1 = Gender;
X_2 = Age;
X_3 = Education level;
X_4 = Farming experience;
X_5 = Farm size;
X_6 = Household size;
X_7 = Farmer support services;
X_8 = Alternative irrigation;
X_9 = Farming methods;
X_{10} = Subsistence farming practice;
X_{11} = Off-farm activities;
β_0 = Constant;
$\beta_1 - \beta_{11}$ = standardized partial regression coefficients;
μ = Error term.

4. Results

4.1. Farmer Socioeconomic Factors

The study findings as presented in Table 1 below reflects the study results on the socio-economic factors of farmers at the study area. Withrespect to the distribution of socioeconomic factors of farmers at the study area, female farmers constitute the majority, accounting for 63.4% of the sample, while male farmers make up 37.6% of the sampled population. Thus, women hold the predominant role in the smallholder production systems within this study area. The findings reveal that most farmers, comprising 39.7%, are aged over 60. In contrast, farmers between the ages of 20 and 29 are in the minority, constituting only 9.2% of the total, with the remaining 51.1% distributed among three other age groups:

30–39 years, 40–49 years, and 50–59 years, respectively. Consequently, the population of farmers in the study area can be characterized as predominantly middle-aged to elderly.

Table 1. Farmer socioeconomic factors, variables, and percentages.

Socioeconomic Factors	Variables	Percentage (%)
Gender	Male	37.6
	Female	63.4
Age	20–29 years	9.2
	30–39 years	11.4
	40–49 years	18.4
	50–59 years	21.3
	≥60 years	39.7
Formal educational level	No school	20.6
	Primary school	27.7
	Secondary school	42.6
	Post-secondary school	9.2
Farm experience	≤1 year	6.4
	2–5 years	19.2
	6–9 years	21.3
	10–13 years	14.2
	≥14 years	39.0
Farm size	≤1 acre	25.5
	2–4 acres	24.1
	5–8 acres	44.7
	9–12 acres	5.7
Household size	1 member	0.7
	2–5 members	33.3
	6–8 members	39.0
	9–11 members	17.0
	≥12 members	9.9
Farming methods	Organic farming	41.1
	Shifting cultivation	25.5
	Crop rotation	14.9
	Intercropping	5.0
	Inorganic farming	13.5
Subsistence farming practice	Yes	85.8
	No	14.2
Alternate irrigation practice	Yes	87.9
	No	12.1
Access to farmer support services	Yes	58.2
	No	41.8
Engagement in off-farm activities	Employed	14.9
	Nonfarming business	24.1
	Social grant	18.4
	Pension (old age grant)	27.0
	No off-farm income	15.6

With regards to the level of education among smallholder farmers at the study area, 42.6% of farmers possessed formal secondary school education, whereas 27.7% of farmers had completed formal primary school education. A minor 9.2% of farmers have post-secondary school education exposure, and 20.6% of farmers have never been through the formal education system. The educational level in the study area is satisfactory, as most of the farmers attended formal education until secondary school, where a learner is expected to read, write, and interpret literature. Therefore, farmers will be able to read the literature and instructions on the use of new technology.

A significant majority, 39.0% of the interviewed farmers, have accumulated over 14 years of farming experience, while the smallest group, at 6.4%, comprises those with less than one year of farming experience. Additionally, 54.7% of farmers have between

2 and 13 years of experience, suggesting that the farmers in the study area are adequately experienced, making it easier for new technology to be adopted.

In terms of farm size, a 44.7% majority of farmers are within the farm size range of 5–8 acres, followed by 25.5% of farmers with less than an acre of farmland. Moreover, 24.1% of farmers are within the range of 2–4 acres, and farmers with the least farmland make up 5.7%. Therefore, the size of the production systems in the study area is large enough to allocate some portions of the farmland to testing new technology. In addition to some adoption factors having a negative impact on farm size, farm size greatly impacts technology uptake, both positively and negatively.

The majority (39.0%) of farmers live in households comprising 6–8 household members. A minority 0–7% of the farmers live alone or in households consisting of one member. Those who are in the range of 2–5 members make up 33.3% of the total sample of farmers, with those having more than 8 members making up a combined (9–11 members and ≥12 members) percentage of 26.9%. This suggests that most smallholder farmers have adequate human resources for labor-intensive technology or farm activities.

Farming methods refer to the practices and techniques used by farmers to cultivate crops or raise livestock [54]. These methods can vary widely depending on factors such as climate, soil type, available resources, and cultural traditions [54]. When it comes to the farming methods used at the study area, organic farming is the most preferred farming method, with 41.1% of the participants having adopted it in their farms, followed by shifting cultivation at 25.5%. Intercropping is at 5.0%, while both crop rotation and inorganic farming make up 28.4% of approaches applied in the study area. Therefore, organic farming is the widely preferred farming method among smallholder farmers in the study area. The implication is that organic farming often requires less water than conventional farming, as it focuses on building soil health and relying on natural processes rather than chemical inputs [55]. This could have a positive impact on water management in the area, as less water would be needed for irrigation.

With respect to the practice of subsistence farming among smallholder farmers at the study area, 85.8% of farmers agree to practicing subsistence farming, with only 14.2% of farmers not farming for the sole purpose of producing food for their households but to also sell their surplus to the informal market, mainly within the rural community. The rationale behind the results showing a strong involvement of farmers in subsistence agricultural production is the lack of economic opportunities and poor living standards in the rural community. Thus, the food produced by the smallholder farmers is used to meet household nutritional needs, and the surplus is sold locally.

In the case of the application of additional irritation water to meet crops' water requirements, the findings depict that 87.9% of farmers in the study area are applying additional irrigation water artificially to meet their crops' water requirements. Only a few (12.1%) of the farmers supplement the shortfall of rain or seek alternative irrigation methods for their farms. This approach results in such farmers becoming solely reliant on groundwater, rainfall, and soil moisture for most of their irrigation water needs. Moreover, the water used to artificially irrigate farms is mostly from municipal sources supplied for domestic use. Subsequently, water is stored in tanks and on-farm ponds at the study area from several sources, including wells, municipal-derived water, rainfall, and water streams, to be later dispersed across the farm manually with watering cans. Hence, this suggests that smallholder farmers can meet most of their crops' water needs in the study area.

Most farmers (comprising 58.2% of the study population) receive support from the state in the form of fertilizer, seeds, irrigation equipment, agricultural training, and agricultural grants in the form of vouchers and fences to secure their farming fields. Only 41.8% of farmers are self-reliant and/or have never received any agricultural support, compared to many farmers who are supported through public or private initiatives to overcome challenges. The findings serve as a testament to farmers' access to extension support services. A substantial 27.0% of smallholder farmers in the study area receive pensions. Following this, 24.1% of farmers are involved in off-farming businesses. Additionally, 14%

of farmers are not fully dedicated to farm-related activities due to alternative employment commitments. Furthermore, 15.6% of farmers solely rely on income generated from farming activities without any supplementary streams of income. Moreover, 18.4% of farmers receive grants, primarily for childcare or disability support. Importantly, a significant portion of farmers participate in off-farm activities to augment their earnings. This approach allows them to allocate portions of their earnings towards acquiring new farming technologies or inputs, potentially improving overall agricultural practices.

4.2. Empirical Results of the Study

For determining if formal water management systems are accepted or not by smallholder farmers at the study area, the socioeconomic factors (independent variable) of smallholder farmers are measured against the dependent variable (Y = acceptance of formal water management systems) using the binary logistics regression model to assess if they influence the acceptance of formal water management systems. The degree to which the model can account for the variance in the dependent variable is indicated by Cox & Snell and Nagelkerke. According to the Cox & Snell (0.19) and Nagelkerke (0.27), for this study, this group of factors accounts for between 19% and 27% of the variability.

The model's findings, as highlighted in Table 2, show that smallholder farmers' gender at the study area is statistically significant, with p = 0.025, and positively influences the acceptance of formal water management systems, with β = 0.955. This means that the likelihood that gender will affect the acceptance of formal water management systems increases by 0.955 when the gender in the model is increased while the other model variables are held constant. In addition, the independent variable "age" was also found to have a statistically significant p-value of 0.186, and it is positively linked with the acceptance of formal water management systems, with β = 0.260. The likelihood that age will affect the adoption of formal water management techniques rises by 0.260 if the variable "age" is raised while keeping all the other factors in the model unchanged.

Table 2. The acceptance of formal water management systems by smallholder farmers.

	β.	S.E.	Wald	df	Sig (p).	Exp (β)	95% C.I. for EXP (β)	
							Lower	Upper
Gender	0.955	0.427	50.001	1	0.025 **	20.598	10.125	50.999
Age	0.260	0.196	10.751	1	0.186 *	10.296	0.883	10.905
Educational level	0.397	0.232	20.933	1	0.087 *	10.487	0.944	20.342
Farming experience	−0.171	0.220	0.606	1	0.436	0.843	0.548	10.296
Farm size	0.373	0.260	20.064	1	0.151 *	10.452	0.873	20.416
Household size	−0.492	0.241	40.159	1	0.041 **	0.611	0.381	0.981
Farming methods	−0.077	0.149	0.269	1	0.604	0.926	0.692	10.239
Subsistence farming practice.	−0.727	0.667	10.187	1	0.276	0.484	0.131	10.787
Alternative irrigation.	20.313	0.662	120.201	1	<0.001 **	100.105	20.760	370.001
Farmer support services.	0.087	0.411	0.045	1	0.832	10.091	0.488	20.442
Off-farm activities	0.051	0.176	0.083	1	0.773	10.052	0.745	10.486
Constant	−40.505	10.358	110.009	1	<0.001	0.011		

Statistical significance level is 0.05 (**) and 0.1 (*).

The farmer's educational level, as an independent variable, was found to be statistically significant, with a p = 0.087 and β = 0.397, indicating that education has a positive effect on the acceptance of formal water management systems. The implication of this result is that with an increase in the educational level of a farmer, while holding all other model variables constant, there is a 0.397 percent chance that formal water management techniques will be accepted. Moreover, the acceptability of formal water management systems is positively influenced by farm size, as highlighted in Table 2, with β = 0.373 and a statistically significant $p = 0.151$. The likelihood that farm size will affect whether formal water management schemes are accepted is 0.373, provided that other model variables remain constant.

However, contrary to the above findings, household size is also statistically significant, with $p = 0.041$; yet it has a negative impact on the farmers' decision to accept formal water management systems, with β = −0.492. When household size as a parameter is increased while maintaining the other factors of the model used at a constant, the probability of household size being an influential factor for the farmers' decision to accept formal water management systems decreases by −0.492. Lastly, the use of alternative irrigation by smallholder farmers, as presented in Table 2, is statistically significant, with $p = < 0.001$, and shows a positive influence on the acceptance of formal water management systems in the study area, with β = 2.313. An increase in alternative irrigation while all other variables remain constant demonstrates a 2.313 increase in the probability of farmers accepting formal water management systems.

5. Discussion

5.1. Farmer Socioeconomic Characteristics

Generally, research has shown that women often play a crucial role in managing water resources and ensuring food security in smallholder farming communities across Sub-Saharan Africa [56]. Hence, having more women at the study area involved in the decision making about water management could potentially lead to better acceptance of formal water management systems. However, female smallholder farmers face limitations such as time constraints, as highlighted by [57], who corroborates that women bear the brunt of time-intensive household tasks in many rural and cultural societies, as opposed to their male counterparts. Considering the observations of [58], these findings suggest that despite women's prominent roles in farming activities in the study area, they might face challenges in adopting new technologies due to limitations stemming from cultural and patriarchal norms. However, the availability of resources plays a crucial role in influencing farmers' inclination towards adopting innovative practices, as indicated by [59], rather than gender itself. Therefore, it is important for government, nongovernmental organizations, and other stakeholders to promote equitable access to resources, training, knowledge and information, and advisory services for both male and female farmers.

With regards to having a low percentage of younger farmers in the study area, in accordance with [33], an older farming population is less likely to accept risky or innovative agricultural technologies when compared to younger farmers. However, in a community that is dominated by middle-aged and elderly farmers, one important strategy to increase the acceptance of water management systems is to make sure that the systems are designed with their needs in mind [60]. For example, systems should be easy to use, low-maintenance, and accessible to those with limited mobility. Additionally, it is important to involve the entire community in the decision-making process, and to make sure that everyone has a voice in the discussion. This can help to ensure that everyone feels invested in the success of the system. When coming to the levels of educational attainment at the study area, it is said that the level of exposure to formal education has an influence on a farmer's desire to use innovative agricultural techniques [61]. Furthermore, the more a farmer has been exposed to a higher degree of formal education, the more likely he is to be able to access, comprehend, and apply agricultural innovation [62]. Higher education has a positive effect on farmers' attitudes about new technology as it helps farmers become more analytical, logical, and aware of the advantages of the new technology [63].

Farming experience is a vital component in technology adoption, as the more experience a farmer has, the more likely new technology will be adopted [64]. Experienced smallholder farmers can better use their skills and knowledge gained through experience to assess the risks and benefits linked with adopting new technology [65]. According to [66], it was observed that, due to productivity and the need to learn by doing, farmers gradually switch from traditional technology to new technologies as they gain new skills over time. Farming experience is most beneficial when a newly developed technology is introduced, as farmers can assess its unique benefits and risks by applying past experiences gained with prior technologies [67]. Based on the study findings, most smallholder farmers have enough farmland that can be used for a variety of initiatives such as testing new technology. When compared to smaller farms, size-reliant technology can only be used on larger farms [68]. Hence, farmers can only adopt farming technology that is not size-reliant, such as large machinery. Other farmers have an edge over those with smaller farms since they can allocate more of their land to testing out new techniques [69]. However, Ref. [70] states that farm size has little impact on other farming practices and initiatives, such as integrated pest management (IPM).

Household size is a significant labor supply alternative that may also affect adoption choices. The adoption of labor-intensive sustainable practices is more likely to occur in farm households with more members [71]. Earlier, [72] stated that smaller family sizes are linked to low rates of adoption when studying the social and economic aspects affecting the adaptability of households to climate change in arid regions of Kenya. Moreover, this is due to the low resource demand of smaller households, such as food, compared to larger households, where expenses are expected to be higher and affect the overall household income negatively, as per [73].

Organic farming, as the most preferred farming method, possesses the potential to enhance soil structure, elevate water retention capacity, mitigate erosion, and reduce the leaching of essential soil nutrients [74]. Additionally, a multitude of agricultural practices can facilitate biological, physical, and chemical transformations within the soil, leading to enhanced water retention and increased plant resilience against droughts, floods, and other extreme weather occurrences [75].

The practice of subsistence farming at the study area can enhance livelihoods and assist in the mitigation of excessive food price inflation. Subsistence farming is crucial in lowering the risk of household food shortages in rural and urban communities [76]. In the study area, farmers engage in cultivating maize during the rainy seasons. Subsequently, the harvested maize is stored for diverse purposes that align with the specific needs of each farm household. To guarantee long-term food security, subsistence farming must be much more effective; this can be accomplished by motivating farmers to seek production intensification that is sustainable and is based on the use of better inputs [77]. The application of irrigation water at the study area by smallholder farmers seeks to supplement the precipitation shortfalls in meeting crop water requirements of their respective farms. Although rainfall dependence reduces the risk of agricultural produce contamination, inconsistent weather patterns could interfere with agricultural production [78]. Thus, owing to the swiftly changing climate, water shortages have become a widespread problem, and droughts are occurring more frequently in South Africa [79]. Nevertheless, using alternative irrigation water to replace rainwater could raise the possibility of contamination in the farming field due to water pollutants [80].

Most farmers at the study area have access to agricultural extension services, as extension agents are liable for raising awareness about inventions, knowledge, and equipment in existence to aid in resolving the difficulties faced by farmers [81]. This denotes that smallholder farmers receive information, skills, technical advice, and motivation through engagement in agricultural extension activities, as per the study findings. Also, the key task of extension specialists is to connect farmers and consumers of novel agricultural technology with the technology's creators or researchers [82].

Access to off-farm income contributes positively to the adoption of new technologies, as a study by [83] has established that the adoption of innovative methods and equipment is linked to off-farm income. This relationship allows individuals in various emerging economies to overcome the credit constraints they typically encounter [84]. In rural areas where financial markets might be absent or dysfunctional, the utilization of off-farm income acts as a substitute for borrowed funds [85]. The importance of off-farm income stems from its capacity to offer farmers readily available capital that can be invested in procuring productivity-enhancing resources such as improved seeds and fertilizers, as noted by [86]. This financial resource derived from nonfarm activities enables rural farmers to afford essential production inputs, including seeds, fertilizers, and the renting of tractors for cultivation purposes.

5.2. Empirical Results of the Study

The implication for gender positively influencing the acceptance of formal water management systems is that people of different genders may have different levels of acceptance when it comes to formal water management systems. However, understanding these trends can help in the designing of programs and policies that are more likely to be accepted by the people they are intended to help. The study's findings are in keeping with [87], who postulated that the household leader's gender had a substantial influence on the adoption of agroforestry technology. On the other hand, Ref. [87]'s data from 2022 show that women were more likely than men to engage in agroforestry. Another shows that the adoption of improved rice cultivars is favorably influenced by gender, according to [88]'s research. Therefore, the decision to embrace formal water management methods is influenced by gender at the study area.

In relation to age, the study found that as farmers become older, they are more likely to accept formal water management systems [65]. This is an interesting finding as it implies that older farmers might have more experience with water management systems, so they are more likely to accept them [64]. However, when compared to younger farmers, an elder farmer can evaluate new technologies with more accuracy due to the information and expertise they have accumulated over the years [89]. In contrast, younger farmers are more likely than their older counterparts to adopt riskier practices and cutting-edge technologies, as younger farmers are more likely to take risks and have more exposure to new technology, making them technologically knowledgeable [85]. This finding is in keeping with [84], who posited that the age of an individual farmer had a substantial impact on the adoption of machine-guided systems. Lastly, it is also worth considering whether other factors when it comes to the acceptance of formal water management systems by smallholder farmers, like education level or economic status, might be influencing this relationship.

Having the educational level of smallholder farmers at the study area positively influencing the acceptance of formal water management systems means that farmers are more likely to be able to understand and use the technology involved in these systems. In addition, a higher level of education can lead to a greater understanding of the benefits of formal water management systems, such as increased water efficiency and reduced environmental impact. When attempting to investigate the trends in the adoption of climate change strategies among smallholder farmers, Ref. [87] found that the educational level had a favorable impact on the adoption of these tactics. According to [88], educated farmers are often more aware of climate change and the effects of climate change on farming. Ref. [87] suggested that education improves farmers' skills and the assimilation of knowledge while enhancing the rate of innovation and technology adoption.

One of the main implications of having farm size positively influence the acceptance of formal water management systems is that farmers with larger farms may be more willing to invest in these systems due to having more access to resources [90]. The use of technology is being accelerated by farmers with larger farms since they have more financial resources and available land area [91]. Moreover, they can purchase more advanced and cutting-edge technology and are risk-tolerant if the technology malfunctions. Farm size positively and significantly correlates with adoption, according to research by [92] assessing sustainable soil and water conservation methods. According to [93], the size of the farm has a considerable beneficial impact on the adoption of improved rice varieties in Nigeria. Therefore, larger farms may also have more space available for installing and maintaining these systems, and may have more human capital that can be trained to operate them.

Household size at the study area is statistically significant and it is negatively associated with the acceptance of formal water management systems by smallholder farmers.

However, a negative coefficient means that as the household size increases, the acceptance of formal water management systems decreases [94]. In other words, the more people there are in a household, the less likely they are to accept formal water management systems. This could be for a variety of reasons such as larger households might have less access to resources, or that they have more competing priorities [95]. The other reason could be that decision making is more difficult in larger households, making it harder to come to a consensus about accepting a new system [94]. These results are in line with those of [96], who examined the socioeconomic traits of farmers and showed that household size had a negative impact on the adoption of modern weed management techniques by farmers. This is probably a result of low household income, which leaves little money for investments in the farm [97].

With regards to the use of alternative irrigation methods, the findings imply that farmers who are already using alternative irrigation methods would be more likely to accept formal water management systems, since they are already familiar with the concept of supplementing rainfall with other sources of water [98]. This finding could have implications for how we promote the adoption of formal water management systems, since it suggests that focusing on farmers who are already using alternative irrigation methods may be a good strategy. It may also suggest that providing information about the benefits of formal systems could be especially effective for farmers who are already using alternative irrigation methods. The use of alternative irrigation is promoted because it may lower the risk involved in crop production, which leads to increased input utilization, greater agricultural yields, enhanced crop output, and crop variety [99]. Therefore, there is a likelihood that farmers' incomes will increase owing to the increase in marketable surplus and commercial activity [100].

6. Conclusions

The acceptance of formal water management systems in the study area is largely influenced by the farmers' gender, age, educational level, farm size, household size, and the use of alternative irrigation. However, even though household size is a significant socioeconomic factor in predicting the acceptance of formal water management systems in the study, it is negatively associated with the acceptance of formal water management systems. The study emphasizes the necessity for collaborative efforts amongst agricultural experts, policymakers, smallholder farmers, and local communities. These collaborations will be instrumental in fostering the widespread acceptance of formal water management systems, thereby enhancing resilience in the face of evolving climatic and agricultural dynamics.

The research not only highlights the link between socioeconomic factors and farmers' decisions but also underscores their influence on the acceptance of formal water management services. In conclusion, this study bridges the gap between theoretical knowledge and practical implementation by shedding light on the complex interplay of factors that shape the trajectory of the acceptance of formal water management systems among smallholder farmers. The implications of these findings are far-reaching, underscoring the significance of holistic, context-specific strategies to achieve sustainable agricultural practices in the face of mounting challenges related to water scarcity and changing climatic conditions.

Study Limitations

Logistical issues such as time, money, and access to various agricultural groups and communities may make it difficult to carry out a study examining smallholder farmers' acceptance of formal water management systems at different locations. It might not be possible to complete the research project in time to coordinate, gather, and analyze the amount of data needed for such a study at several locations.

Furthermore, evaluating smallholder farmers' acceptance of formal water management systems solely based on water quantity may result in missing significant socioeconomic and cultural aspects that affect their attitudes and practices. Water quantity is obviously important for agricultural output, but farmers' acceptance of formal water management systems can also be greatly impacted by other aspects like water quality, accessibility, price, and compatibility with current farming practices. Strictly concentrating on the amount of water available could oversimplify the intricate dynamics at work and result in missing the subtle motivations behind farmers' acceptance or rejection of formal water management schemes. Therefore, in order to fully comprehend farmers' views towards these systems, a more thorough approach taking into account a variety of elements is required.

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Appendix A

Table A1. Independent variables hypothesized to influence the acceptance behavior.

Variable & Code.	Operational Variables.	Measurement Unit.	Expected Sign.
Gender (GDR).	A social and cultural construct for being male or female.	Male = 1, Female = 2	+/−
Age (AGE).	The amount of time in years a person has lived.	20–29 years = 1, 30–39 years = 2, 40–49 years = 3, 50–59 years = 4, ≥60 years = 5	−
Education level (EDU).	Exposure to formal learning environment.	No school = 1, Primary school = 2, Secondary school = 3, Post-secondary school = 4	+
Farming experience (EXP).	Number of years a farmer has been practicing farming.	≤1 year = 1, 2–5 years = 2, 6–9 years = 3, 10–13 years = 4, ≥14 years = 5	+
Farm size (SIZ).	The total size of cultivated land.	≤1 acre = 1, 2–4 acres = 2, 5–8 acres = 3, 9–12 acres = 4, ≥13 acres = 5	+
Household size (HHS).	The number of individuals residing in the household	1 person = 1, 2–5 people = 2, 6–8 people = 3, 9–11 people = 4, ≥ 12 people = 5	−
Farming methods (MET).	Methods used to cultivate crop or manage the farming system.	Organic farming = 1, Shifting cultivation = 2, Crop rotation = 3, Intercropping = 4, Inorganic farming = 5	+/−
Subsistence farming practice (SUB).	Growing crops for the sole purpose of feeding a farmer's households and in some instances, the surplus produce is sold.	Yes = 1, No = 2	−

Table A1. *Cont.*

Variable & Code.	Operational Variables.	Measurement Unit.	Expected Sign.
Alternative irrigation (IRR).	The use of additional irrigation water to supplement crop water shortages owing to low precipitation.	Yes = 1, No = 2	+
Farmer support services (FSS).	Farmer support from government	yes = 1, No = 2	+
Off-farm activities (OFA).	Revenue generated from off-farm related activities.	Employed = 1, Off-farm business = 2, Social grant = 3, Pension = 4, None = 5	+

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