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Examining Smallholder Farmers' Perceptions of Irrigation Access: Evidence from South and North Tongu Districts of the Volta Region, Ghana

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Abstract: *Past studies demonstrate that smallholder farmers perceive irrigation access as an infrastructure and socio-economic constraint. Cultural norms, prevailing local agricultural practices, historical and personal experiences influence farmers' perceptions of irrigation access. In Ghana, especially in the Volta Region, the case is similar. However, some studies found that smallholder farmers' perceptions of irrigation depend on the geographical location of farms, farm size, access and proximity to water sources, and socio-economic status. Other studies examined farmers' irrigation infrastructure and water management needs from technical perspectives in the Volta Region. However, there are limited studies on the perceptions and needs of farmers who directly depend on these irrigation systems. This study examined smallholder farmers' perceptions of irrigation access and needs in Ghana's Volta Region. A structured questionnaire survey was randomly administered among 282 smallholder farmers in South and North Tongu Districts from January to February 2024 to establish their perceptions of irrigation access and needs. The data was analyzed using SPSS and Excel, and we correlated respondents' socio-demographic characteristics with their irrigation access to understand the factors influencing farmers' perceptions. Our study further employed diffusion* *of innovations and planned behavior theories to explain farmers' irrigation access. We found that those respondents (68%) who irrigated their farms did not have consistent and sufficient irrigation water access. Only 32% accessed enough irrigation water. Overall, respondents (74%) perceived inadequate infrastructure as the main reason for unreliable irrigation water access. Some respondents (68%) said it was difficult to access irrigation water because water sources were not close enough. Even the cost of connecting irrigation ditches to farms (93%) and the energy/electricity cost of pumping water (89%) were high. Respondents (89%) perceived that irrigation requires additional maintenance costs, and they did not have enough funds to implement it. As such, irrigation was reserved for the rich in society. Theoretically, individual farmers might adopt new technologies or practices over time. Farmers' behavior is determined by intention, which is influenced by attitudes, subjective norms, and perceived behavioral control. Household income, education, and gender influenced farmers' perceptions of irrigation access. The study used the diffusion of innovations theory to explain how farmers' perception of irrigation is influenced by relative benefits, compatibility with existing practices, and visibility among peers. It also highlighted how attitudes, and social pressure influenced adoption. The findings suggest that incorporating a water access strategy into the districts' development plans can improve infrastructure and farmers' resilience.*

Keywords: smallholder farmers, perceptions, irrigation access, Volta region, Ghana

INTRODUCTION

Smallholder farmers in Sub-Saharan Africa perceive irrigation access as involving more than physical infrastructure for irrigation water access (Burney et al., 2013). Farmers' perception of irrigation is based on their education level and the extent of their exposure to irrigation. It is also dependent on their expertise, experience, and knowledge they have with irrigation (Fahad et al., 2020). Past studies have determined that farmers' perception of irrigation access was influenced by cultural norms, historical experiences, socio-economic conditions, and the environment (Jafary and Bradley, 2018; Nguyen et al., 2016). Other studies found that farmers' views of irrigation access were influenced by the topography of the area, socio-economic development levels, and the prevailing cultivation practices in the area (Chuchird et al., 2017; Limantol et al., 2016; Udmale et al., 2014).

In Ghana, smallholder farmers' perception of irrigation access significantly depends on the geographical location of their farms, proximity to water sources and rainfall amount (Akrofi et al., 2019; Kumasi et al., 2019; Limantol, et al., 2016). Some farmers perceived that to have access to irrigation, their farms must be located near water sources (Ayamga et al., 2016; Bugri, 2008; Dakpalah et al., 2018; Namara et al., 2014). Past studies found that farms were not close enough to water sources, which negatively affected farmers' perceptions of irrigation access (Atiah et al., 2019; Dasmani et al., 2020; Kyei-Baffour & Ofori, 2006). In the more dry and semi-arid environments in Ghana's Northern, Upper East, and Upper West regions, farmers tend to view irrigation access as an essential tool for their production (Sekyi-Annan et al., 2018). Similarly, Akudugu et al. (2021) found that these farmers had a more positive perception of irrigation access. This is because these farmers relied on irrigation to mitigate the effects of climate change and improve yields. Other studies have also indicated that farmers living in areas with inconsistent rainfall perceive access to irrigation as essential for secure crop production (Fagariba et al., 2018).

Some irrigation projects and initiatives were made available to farmers by the Ghanaian government and international agencies, such as the Japan International Cooperation Agency (JICA) (Baldwin & Stwalley, 2022). However, not every region, districts or communities had benefited equally from these irrigation initiatives. (Higginbottom et al., 2021; Namara et al., 2011). Farmers who had access to these irrigation projects had more positive perceptions of irrigation due to their first-hand experience with the benefits (Zakaria et al., 2020). In those regions where irrigation projects are not available, farmers are less likely to prioritize irrigation access. These farmers do not seem to fully appreciate irrigation benefits because traditional rain-fed agriculture is dominant in the area and requires no irrigation expenses. Therefore, these farmers experienced insufficient water access, low productivity, and poor yields due to inherited rain-fed farming practices (Anaba, 2016; Assan et al., 2020; Balana et al., 2020; Eshete et al., 2020; Zarei et al., 2020).

Farmers' perceptions of irrigation access can be explained by several theoretical frameworks from social science, behavioral economics, and agricultural studies. These theories help explain the factors influencing farmers' attitudes, decision-making, and behaviors regarding new technologies such as irrigation systems, in comparison to the traditional rain-fed production system. One such theory is Rogers' (1962) Diffusion of Innovations theory, which explains how new technologies, practices, or ideas are adopted by individuals or groups over time (Miller, 2018). Farmers' perceptions of irrigation access can be influenced by their position within the innovation adoption curve – innovators, early adopters, early/late majority, and laggards (Wasito & Hanifah, 2021; Yazdanpanah et al., 2023). Early adopters might perceive irrigation as a means of improving productivity, while others may resist due to uncertainty or perceived risks. Those key factors that might sustain farmers' interest in practicing irrigation include perceived relative advantages (e.g., increased yield and income), compatibility with existing practices, complexity of adoption (e.g., technical know-how), observability of benefits, and trialability of the system.

Additionally, Ajzen's (1991) Theory of Planned Behavior suggests that behavior is determined by intention, which is influenced by attitudes, subjective norms, and perceived behavioral control. Farmers' access to and use of irrigation systems depends on their attitudes, subjective norms, and perceived behavioral control. Individual farmers could use irrigation more when they perceive that the system could provide higher yields or reduce climate risk. The influence of peers, extension workers, or community leaders can boost farmers' confidence in using irrigation systems. In the Volta Region of Ghana, where this study is situated, smallholder farmers tend to exhibit the principles of the Theory of Planned Behavior. Consequently, irrigation adoption rate is low, resulting in decreased yields and crop failures.

Past studies demonstrate that income levels, access to credit, and education influence smallholder farmers' perceptions of irrigation access (Derkyi et al., 2018; Kudadze et al., 2019; Nyang'au et al., 2021; Yamba et al., 2019). Castillo et al. (2021) found that farmers with greater financial resources, education, and knowledge of modern irrigation technologies had a more positive view of irrigation access. Other studies also found that farmers saw irrigation as expensive and difficult (Fagariba et al., 2018; Kyei-Baffour & Ofori, 2006; Nalumu et al., 2021). Asiedu and Gross (2017) found in Northern Ghana that farmers perceived irrigation as being only for the wealthy and the privileged in society. Those farmers with limited financial resources and knowledge perceived irrigation as less accessible or non-beneficial and were skeptical about irrigation (Lefore et al., 2019; Ndamani & Watanabe, 2015). In the Volta Region, previous studies examined the irrigation infrastructure and water management needs of farmers from a technical perspective, leaving a gap in farmers' perceptions of irrigation access. Furthermore, in connection with theoretical studies, little attention has been paid to the perceptions and needs of farmers who directly depend on these irrigation facilities. To bridge this gap and meet the needs of these farmers, it is important to understand how they perceive irrigation access. Therefore, this study examines smallholder farmers' perceptions of irrigation access in the South and North Tongu Districts of Ghana. The findings of this study will help stakeholders and policymakers integrate farmers' perspectives into irrigation development programs, improving infrastructure and water management practices. It will also contribute to the literature on smallholders' perceptions of irrigation access.

THEORETICAL FRAMEWORK

Application of Diffusion of Innovation Theory in Agriculture

Rogers (2004), who is associated with the origin of the Diffusion of Innovation theory in 1962, conducted a study on the adoption of agricultural innovations among farmers in Iowa, perceiving diffusion as a more generalized concept applicable to any type of innovation. From his initial intent of organizing common findings in diffusion research, the model's framework emerged, along with standardized descriptions of related components such as adopter categories. His work provided the structure for the theory as it is known today, with the basic framework and accompanying conceptual components (Jain et al., 2024).

The application of Rogers' Diffusion of Innovation theory in agricultural innovation, as described in 2004, can be seen in how new farming technologies spread. For instance, this theory can be followed in the spread of irrigation system for farmers in Ghana's Volta region. Initially, innovators and early adopters (often large) with positive perceptions can be eager to experiment with the new technologies. As the success of these innovations becomes more evident, the perceptions of other farmers can change, and they may more easily adopt irrigation as an innovative technology. Moreover, when these farmers observe the economic benefits and the effectiveness of this new innovative irrigation practice spreading through their social networks, their perceptions might change.

Past studies showed that relative advantage, compatibility, complexity, trialability, and observability are key elements that influence perception of technology adoption in diverse sectors, including technology, education, healthcare, and agriculture (Jain et al., 2024; Rogers, 2003). The following elements influence farmers' perceptions and adoption of new agricultural innovations:

Relative advantage**:** The degree to which an innovation is perceived as better than the idea, practice, or product it replaces.

Compatibility**:** How consistent the innovation is with the existing values, experiences, and needs of potential adopters.

***Complexity*:** How difficult the innovation is to understand and use.

***Trialability*:** The ability to experiment with the innovation on a limited basis before full adoption.

***Observability*:** The extent to which the results of an innovation are visible to others.

According to Rogers' Diffusion of Innovation Theory, there are five adopter categories, which are briefly described below:

***Innovators*:** Those who are the first to adopt an innovation.

***Early Adopters*:** Those individual farmers and opinion leaders who influence others in the community to adopt an innovation.

***Early Majority*:** Individual farmers who adopt innovations just before these innovations become widely accepted by others.

***Late Majority*:** Individual farmers who adopt innovations only after these innovations have been widely accepted by others.

***Laggards*:** Those individual farmers who are last to adopt an innovation, often due to skepticism or lack of resources.

The adoption stages, in the case of our study, depend on the perception of each farmer. Therefore, irrigation adoption requires an understanding of Rogers' framework. In such cases, policymakers, researchers, and development agencies can develop targeted interventions to influence farmers' perceptions and promote the diffusion of agricultural innovations in communities. Moreover, adopting tailored communication strategies and engaging key stakeholders can influence farmers' perceptions and enhance the likelihood of successful innovation diffusion in farming communities in Ghana.

Rogers (2004) emphasized that the framework offers a useful lens for examining and analyzing the dynamics of agricultural innovation perceptions, particularly with resistance to change. It highlights the importance of understanding the interaction between innovation, communication, time, social systems, and the categories of adopters mentioned above to ensure successful diffusion in agriculture. In the agriculture sector, Rogers' theory has been instrumental in explaining how new technologies, such as irrigation systems, improved seeds, and farming machinery, spread among farmers (Rogers, 2003). In the case of the Volta region of Ghana, this is also applicable to understand how farmers perceive irrigation access.

Several studies have applied the theory to explain how innovations like new crop varieties, irrigation techniques, machinery, and sustainable farming practices diffuse in rural communities. For instance, a study by Alemu et al. (2017) explored the adoption of improved maize varieties in Ethiopia and found that relative advantage (improved yields), trialability (small-scale testing), and observability (visible results of adoption) were key drivers that influence farmers' perception of irrigation adoption. The study further noted that early adopters played a significant role in influencing the decisions of late adopters, consistent with Rogers' categorization of adopters (Alemu et al., 2017). In India, Suresh and Mishra (2019) applied Rogers' theory to understand the adoption of conservation agriculture techniques. Their study highlighted that the adoption of zero-tillage and crop rotation was influenced by the compatibility of these practices with traditional farming systems, as well as the observable benefits in terms of soil health and reduced labor costs (Suresh & Mishra, 2019). The findings were in line with Rogers' claim that innovations that align with existing values and needs are more likely to be adopted by farmers.

Challenges in the Diffusion of Agricultural Innovations

Despite its widespread application, Rogers' diffusion of innovations theory faces challenges in agriculture irrigation technology adoption, particularly in developing countries like Ghana. Innovators often encounter such challenges as the complexity of innovations, limited access to information, inadequate extension services, and system affordability to influence the diffusion process of new technologies. The diffusion process among early adopters is hindered by resistance due to traditional farming practices, ease of system operation and availability. Past studies demonstrate that government policies, market access, socio-economic constraints, extension services, and environmental conditions, among others, influence the perception of irrigation adoption among innovators, early and late adopters (Hilts et al., 2022; Mesa-Manzano et al., 2023; Patnaik & Bakkar, 2024). A study by Doss et al. (2015) on the adoption of agricultural technologies in Sub-Saharan Africa highlighted the importance of local practices, social networks, and trust in extension services as the determinants of farmers' perception of adoption, in this case, irrigation. The study further pointed out that innovations must be well tailored to local conditions to meet the needs of farmers and influence their perceptions to adopt (Doss et al., 2015).

Furthermore, the late majority and laggards as identified by Rogers (2004) were hesitant to adopt irrigation due to financial constraints and risk aversion. A study by Nascimento et al. (2018) in Brazil examined the adoption of agroforestry practices and found that farmers' reluctance to change and accept new technologies was influenced by their perceived financial risks and uncertainties associated with new practices. Hence the delay in acceptance of new technologies (Nascimento et al. 2018).

Economic factors such as the cost of innovations and farmers' financial resources further influence farmers perception of adoption. Rogers' diffusion of innovations theory suggests that the relative advantages like increased productivity and efficiency of an innovation often lead to its adoption. However, in many cases, especially in developing countries, the initial cost of adopting an innovation can be high, even if the long-term benefits are clear. For example, the adoption of new machinery, irrigation systems, or high-yield crop varieties may require upfront investments that smallholder farmers cannot afford, limiting their perception and widespread adoption of such innovations (Doss et al., 2015; Nascimento et al., 2018).

Rogers' diffusion of innovations theory further propounds that early adopters who are typically more willing to experiment with new practices, may face social pressure or resistance from their peers in the communities. Studies by Suresh and Mishra (2019) affirmed that peer influence, group norms, and social capital played substantial roles in either accelerating or hindering adoption. However, these social dynamics are not fully accounted for in Rogers' framework. In this case, Ajzen's (1991) Theory of Planned Behavior can be adopted and jointly used with Rogers' Diffusion of Innovations theory to explain farmers' perception of irrigation access. As mentioned earlier, the theory of planned behavior states that farmers' access to and use of irrigation systems depends on their attitudes, subjective norms, and perceived behavioral control.

Furthermore, Rogers' model emphasizes the initial stages of adoption. However, it does not also fully address the long-term sustainability of innovations. While an innovation may be adopted, its continued use and success depend on factors like maintenance and continuous training. Nascimento et al. (2018) found that some innovations in agriculture may show initial success but might fail to provide sustained benefits over time. This failure could be attributed to poor maintenance, management, economic constraints, inadequate technical know-how to repair and maintain new technologies like irrigation facilities (Nascimento et al., 2018).

Diffusion of innovations theory tends to focus on the diffusion of technology or innovations as a linear process (Rogers et al., 2014). This can overlook the complex interplay between technology, society, and the environment (Voulvoulis & Burgman, 2019). In agriculture, the introduction of technological innovations does not always lead to positive outcomes (Huang & Wang, 2024). For example, the spread of chemical fertilizers and pesticides has often led to environmental degradation and health risks (Hossain et al., 2022). However, Rogers' diffusion of innovations theory does not sufficiently explain this situation (Peshin et al., 2019). Moreover, the assumption that technological innovations inherently lead to improvements can sometimes ignore these unintended consequences (Foster & Rosenzweig, 2017). For this reason, some other theoretical frameworks could be adopted to explain the unintended consequences of Rogers' theory of diffusion of innovation (Goss, 1979; Yoder-Wise, 2013). As indicated earlier, Ajzen's (1991) Theory of Planned Behavior could be adopted and jointly used with Rogers' model to explain the unforeseen circumstances or the unintended consequences.

Theory of Planned Behavior

The theory of planned behavior offers an important basis for explaining farmers' decisions about the adoption of agricultural innovations including chemical fertilizers and pesticides (Ajzen, 1991; Bagheri et al., 2019). The theory asserts that behavior is influenced by attitude, subjective norms, and perceived behavioral control (Kashif et al., 2018; Mohammed et al., 2017). For instance, farmers might develop favorable perceptions of pesticides and fertilizers if they perceive these technologies to boost crop yield, increase income, or reduce labor costs. Moreover, if colleague farmers, extension workers, or retailers advocate for the use of these chemicals, farmers may experience social pressure to comply, thereby strengthening their intention to adopt (Bakker et al., 2021; Enwerem et al., 2022). When farmers perceive they have the capabilities, ease of access, and knowledge and skills to use these technologies well, they are likely to adopt (McCormack et al., 2021).

The theory of planned behavior clarified why farmers may continue to use these pesticides despite knowing their harmful effects on the environment, soil, and health risks (Mitter, 2022; Monfared et al., 2015; Yazdanpanah et al., 2019). If the real benefits (e.g., enhanced yield or financial profit) exceeds the perceived risks, farmers may be encouraged to continue to use it. Similarly, social norms can minimize concerns regarding long-term dangers if peers or governing bodies emphasize short-term output (Kinzig et al., 2013). Despite farmers' awareness of harmful effects, a robust feeling of behavioral control – characterized by confidence in chemical management or belief in personal preventive measures – can result in continued adoption (Ali et al., 2020). Consequently, the theory of planned behavior complements the diffusion of innovation theory to some extent in addressing both the drivers for the adoption of innovations and the continuation of potentially harmful practices (Dearing & Cox, 2018).

The theory of planned behavior can be relied on to understand farmers' perception of irrigation access and its possible consequences (Ajzen, 1991), which include water overexploitation, soil salinization, or decline in water resources (Castillo et al., 2021). Farmers are more inclined to employ irrigation when they have a positive view towards its benefits (Giordano & de Fraiture, 2014). For instance, improved crop yields, less reliance on rainfall and drought mitigation could give farmers a positive perception about irrigation access. With regards to subjective norms, if community leaders, peers, extension workers, or market pressures advocate for irrigation use, farmers may experience social pressure to comply (Tozier et al., 2018). Likewise, seeing respected farmers in the community adopt irrigation can create a normative pull (Hoogesteger et al., 2023). Furthermore, if farmers perceive that they have the necessary resources, knowledge, and infrastructure to utilize and manage irrigation systems, a sense of agency could influence the likelihood of adoption (Mdoda et al., 2023; Sookhtanlou, 2018). Farmers might continue to use irrigation systems despite recognizing the possible damage it could cause to the environment if they perceive the immediate benefits outweigh the long-term risks (Antunes et al., 2017; Elijah & Odiyo, 2019; Makone et al., 2021). Moreover, if farmers trust in the irrigation system's ability to mitigate adverse effects of climate change, it could influence them to continue to use it (Azizi-Khalkheili et al., 2021; Woods et al., 2017).

METHODOLOGY

Study Area

This study was carried out in Ghana's Volta Region. The Volta Region has 18 administrative Districts in operation. South Tongu District has a total land area of 665 km^2, which accounts for 7% of the Volta Region's size (9,504 km^2). South Tongu sits 75 meters above sea level. However, North Tongu District has a total land area of 1,154 km^2, which is 12% of the size of the Volta Region. North Tongu District is situated at a slightly higher elevation of 85 meters above sea level compared to South Tongu. Despite the differences in size and elevation, both Districts share a border with the Volta River, providing important water resources for the Volta Region. The diverse landscapes of both Districts, including fertile farmland and lush forests, contribute to the overall beauty and natural resources of the Volta Region.

According to the Ghana Statistical Service (2021), the Volta Region's total population is approximately 1,659,040 individuals, accounting for 5.4% of the national population of 30,832,019 people. Of this total, 790,685 were men. South Tongu District had 113,114 inhabitants, accounting for 6.8% of the Volta Region's total population of 1,659,040. Females make up approximately 60,626 (53.6%) of the total population of South Tongu District. The North Tongu District had a population of 110,891, which accounted for 6.7% of the Volta Region's population. Females make up around 57,895 (52%) of the total population of North Tongu District. A population of 68.9% and 56% in the South and North Tongu Districts, respectively, live in rural areas and rely heavily on agriculture for a living. However, farmers in these rural communities faced challenges such as limited access to irrigation water and infrastructure, which hindered their productivity. Despite these obstacles, the agricultural sector remains the backbone of the local economy, providing employment and sustenance for most residents.

The South and North Tongu Districts are situated in the Coastal Savannah Vegetation Zone. They both have swampy areas that are conducive to agricultural cultivation (Amponsah et al., 2018; Koku, 2001). The Southwest Monsoon Wind creates a distinct climate pattern for these districts. This occurs twice a year and frequently results in a two-fold maximum rainfall regime (Ghana Statistics Service, 2014; South Tongu District Assembly, 1996; Wondergem, 2016). The rainfall from the Southwest Monsoon Wind contributes to the success of agriculture in both South Tongu and North Tongu Districts. It provides the necessary water for crops to thrive. Farmers in these districts have learned to adapt to the unique climate pattern, utilizing it to their advantage in their cultivation practices.

Generally, the combination of swampy areas, water sources, and the distinct districts' climate patterns makes both Districts prime locations for agricultural production. However, farmers' perceptions of irrigation access and needs can greatly impact their decisions on what crops to grow and how much to produce. Some farmers choose to focus on crops that require less water to minimize their reliance on irrigation systems. Others also invest in irrigation technology to maximize their crop output. Additionally, soil quality and market demand also play a role in determining the types and quantities of crops that farmers choose to cultivate in these districts. The success of agriculture in these communities is dependent on farmers' ability to adapt to changing conditions and make strategic decisions based on their individual circumstances.

The rich soil in these districts, combined with the consistent rainfall from the Southwest Monsoon Wind, allows for a variety of crops to be grown successfully, including staples like maize, cassava, and rice. Farmers in the selected communities from the districts have honed their skills over generations, passing down traditional farming techniques that take advantage of the unique climate conditions. By understanding and working with the natural environment, the farmers have been able to sustainably produce food and support their local economy for years.

Farmers in the South and North Tongu Districts rely primarily on agriculture for their livelihoods. The sector contributes significantly to both Districts' efforts to improve food security, alleviate poverty, and create jobs. However, low productivity and yields have reduced the sector's contribution to Ghana's gross domestic product (GDP). This is frequently ascribed to insufficient investment in irrigation infrastructure and land tenure agreements. Agriculture output is often small-scale in the selected localities. Farmers rely more on traditional rain-fed farming, which frequently produces low yields. The smaller farm sizes, high costs of land, fragmentation of lands, and ownership agreements often influence farmers' perception of irrigation. Farmers in the selected communities lack suitable irrigation infrastructure, such as streams and well-developed canal systems.

Smallholder farmers who use irrigation in the districts produce more rice and vegetables than those who rely on rainfall. Irrigated farms exhibit better technical, allocative, and economic efficiency than rain-fed farms (Bidzakin et al., 2018). Crop yields, on the other hand, are frequently low due to the poor status of irrigation, irrigable fields, and irrigation infrastructure in the districts' settlements.

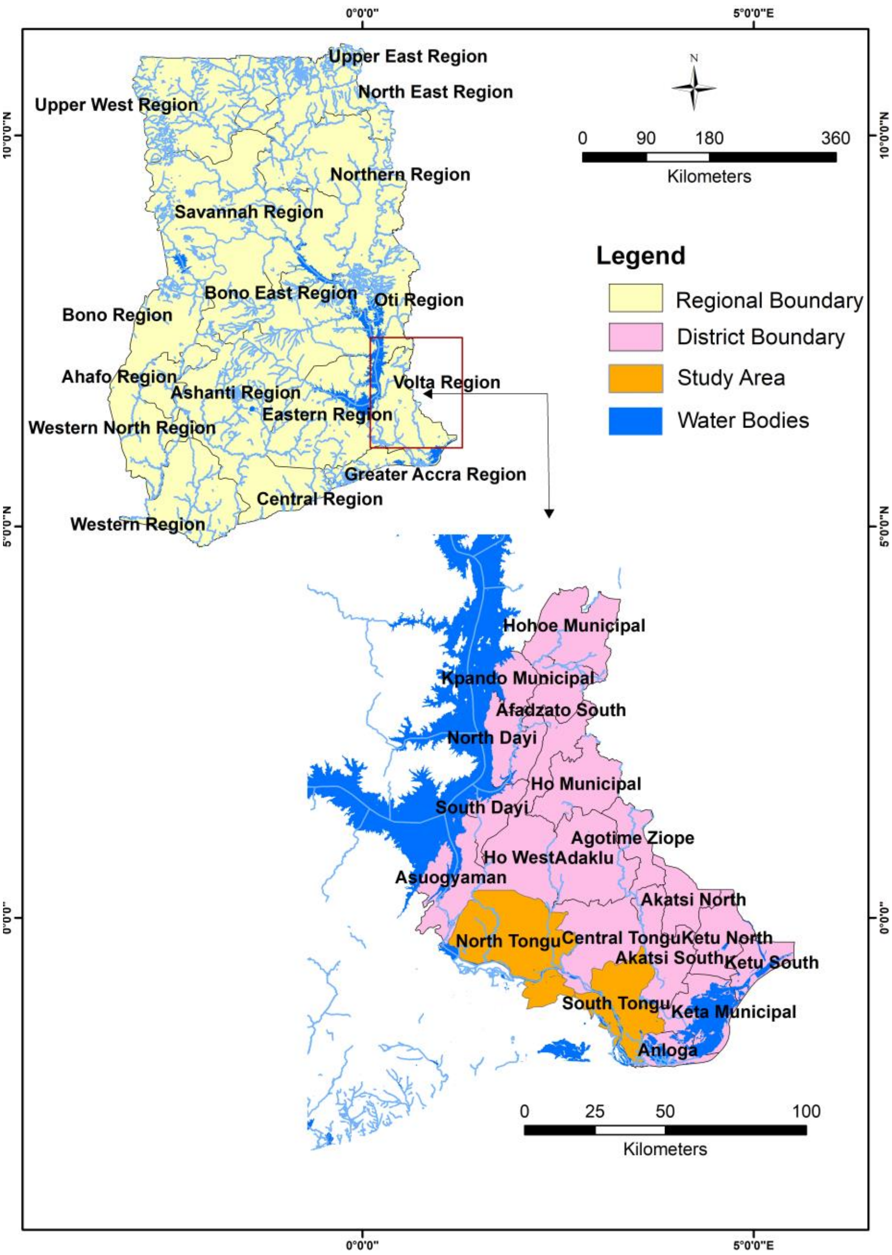

Figure 1: Study Area Map
(Source: UNOCHA, 2024)

Data Collection and Analysis

We chose two potential irrigation districts on purpose from the Volta Region for the survey. The selected districts were South Tongu and North Tongu Districts. These Districts were selected based on existing farming patterns, water sources, irrigation practices, irrigation needs, and culture. Both Districts rely on agriculture as the main source of livelihood for most of the population. Additionally, both South and North Tongu Districts have been experiencing similar challenges with water access and inconsistent rainfall patterns, making this area ideal for our study. By focusing on these two districts, this study will gain valuable insights that can be applied to other similar agricultural regions in the Volta Region.

In December 2023, we carried out an initial household survey in the study area, specifically in Tordzinu and Dorfor-Adidome. Throughout this initial survey, we gathered useful data on the perceptions of smallholder farmers about access to irrigation and their needs for irrigation system development. Subsequently, a carefully designed questionnaire was developed and uploaded onto the digital data collection platform known as Kobotool Box. This simplified the process of collecting data and eventually storing and retrieving it. The survey was carried out with the use of informed consent forms, ensuring that respondents were fully aware of and agreed to take part. Additionally, careful measures were taken to guarantee the anonymity and confidentiality of the respondents.

The Yamane sample size formula has been widely used in previous studies as a reliable method for obtaining the appropriate sample size when the population size is known. Studies have used this method because it ensures that the selected sample appropriately represents the target population without requiring a full census. In these studies, the process involves determining the total number of individuals within the population and selecting a permissible margin of error, typically set at 0.05 or 0.10, as shown in Equation 1 below (Alor et al., 2023; Awuku et ai., 2023; Hasan & Kumar, 2024; Ikehi et al., 2019; Kumah et al., 2023; Usman et al., 2023; Wambaka & Adegbuyi, 2021).

This study uses the Yamane sample size calculation with a 0.05 margin of error to determine the sample size for the study. The sample size was 357 household farmers. However, 75 individuals failed to respond to the questionnaire due to their unavailability, time constraints, and other personal reasons. Some farmers had busy schedules and prioritized other activities over participating in the survey. Therefore, the responses from 282 household farmers were used in the analysis. The Yamane formula is expressed as:

$$n = N/(1 + N(e)^2) \tag{1}$$

Where:

n = required sample size

N = population size

e = margin of error expressed in decimal (0.05)

Using trained enumerators, we administered the questionnaire randomly to 282 household farmers in the selected communities from January to February 2024. The selected communities included Tordzinu, Hikpo, Sokpoe from South Tongu, and Agorveme, Korsive, and Dorfor-Adidome from North Tongu. The selection of these study communities was purposeful, as they exhibited a lack of irrigation usage and inadequate construction of irrigation infrastructure among smallholder farmers. To verify the results of our questionnaire, we conducted interviews with extension officers from the directorate of agriculture in both Districts.

The questionnaire was divided into two main sections. The first section focused on the socio-demographic characteristics of smallholder farmers in the study area, including gender, age, education, household size, household income, farm size, and years of experience in farming. The second section examined smallholder farmers' perceptions of irrigation access and needs in the study area. The survey consists of Likert-scale questions that provided a range of responses to understand the extent of agreement among respondents regarding their perceptions of irrigation access and needs. For our presentation of the results, we utilized descriptive statistics, specifically frequencies and percentages.

In the analysis of our data, we used SPSS software version 27 and Excel to generate tables and figures that present descriptive statistics, specifically frequencies and percentages. In addition, we performed a correlation analysis, to identify the statistically significant link between the socio-demographic characteristics of the respondents and the section 2 questions.

Past econometric studies used the logit model to analyze farmers' perceptions and identify factors influencing their views on a specific agricultural practice, policy, or technology. These studies employed the logit model to analyze the impact of predictor variables like age, gender, education, farm size, and income on various binary dependent variables such as technology adoption, specific policy adoption, perceptions of climate change, perceptions of organic food, and perceptions of agriculture extension services (Dadzie 2023; Habtemariam et al., 2016; Ojha et al., 2023; Uddin et al., 2017; Usman et al., 2023). In this study, the logit regression model is employed to analyze factors influencing farmers' perceptions regarding irrigation access. Those farmers who perceived irrigation access positively were assigned a code of 1, while those who did not were assigned a code of 0. An odds ratio reflects the likelihood of an outcome associated with a one-unit increase in the predictor variable, indicating values greater than 1, less than 1, or neutrality in perception. The irrigation access decisions of farmers do not necessarily affect the decisions of their peers. This concept enables the analysis to consider each observation as an individual data set. No extreme outliers exist in the predictor variables that could bias the results. The equation below depicts the general logit model. The logit model predicts the probability [P(Y=1)] that a farmer has a positive perception (Y=1) versus a negative perception (Y= 0) based on a set of explanatory variables.

$$\ln[P(Y=1)/1-P(Y=1)] = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 \ldots + \beta_kX_k + \varepsilon \quad (2)$$

Where:

$\ln[P(Y=1)/1-P(Y=1)]$ = the log-odds of a positive perception.

β_0 = the intercept.

$\beta_1, \beta_2, \ldots, \beta_k$ = the coefficients for the explanatory variables.

$X_1, X_2, \ldots, X_k$ = the independent variables influencing perception.

ε = the error term.

Y = Farmer's perception of a new agricultural practice or technology (Irrigation access)

Y= 1: Perceives irrigation access positively (e.g., useful).

Y= 0: Perceives irrigation access negatively (e.g., not useful).

The full equation is expressed with all parameters as shown below:

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$\ln[P(Y=1)/1-P(Y=1)] = \beta_0 + \beta_1$gender + $\beta_2$marital status + $\beta_3$education + $\beta_4$age+ $\beta_5$farmland ownership + $\beta_6$farm size + $\beta_7$household income + $\beta_8$household size + ε (3)

Where:

X_1 = Gender of the farmer.

X_2 = Marital status of farmer (Yes/No).

X_3 = Level of education.

X_4 = Age of farmer.

X_5 = Farmland ownership (Yes/No).

X_6 = Farm size.

X_7 = Household income.

X_8 = Household size.

Past theoretical studies have used Rogers' Diffusion of Innovation theory and the Theory of Planned Behavior to explain farmers' perceptions of technology or innovation adoption (Ayanwale & Ndlovu, 2024; Ejigu & Yeshitela, 2024; Kulugomba et al., 2025; Li et al., 2024; Pangestu et al., 2025). Similarly, in this study, Rogers' Diffusion of Innovation theory and the Theory of Planned Behavior were employed to understand farmers' perceptions of irrigation access in the Volta Region of Ghana.

RESULTS AND DISCUSSIONS

Socio-Demographic Characteristics of the Respondents

To understand smallholder farmers' perceptions of irrigation access, several socio-demographic characteristics, including age, gender, education level, household size, and farming experience, were considered. We found that the respondents (71%) were within 40–49, and 50–59-year groups, with an average age of 50 years (Table 1). This means that respondents were aged, and aging farmers were not as open to new technologies like irrigation compared to younger farmers. Instead, they preferred traditional rain-fed farming. It also means that older farmers might struggle to keep up with the changing demands of agriculture. As technology continues to advance and new methods of farming are introduced, older farmers find it difficult to adapt and implement changes like irrigation access. Brown et al. (2019) found that farmers who are older tend to be less adventurous and more risk averse. Similarly, Wang et al. (2015) found that farmers' possibility of adopting irrigation technologies declines with increasing age. However, other studies indicated otherwise. Studies by Bunyasiri et al. (2024) in Thailand and Tai et al. (2024) in Ulanqab City of China demonstrated that aged farmers tend to adopt labor-saving technologies like irrigation.

In connection with the diffusion of innovation theory and the planned behavior theory, individual farmers adopt irrigation in stages usually influenced by their socio-demographic factors. This shows that responding farmers were late majority adopters who exhibited more restraint than innovators and early adopters. They required observable evidence of the irrigation system's effectiveness before committing to its adoption. This correlates with the idea that both the early and late majority are influenced not just by the system's benefits but also by the actions of peers and trusted community leaders. According to the idea of planned behavior, older farmers may exhibit conservative or experience-based attitudes towards change, highlighting the need for demonstrated benefits of irrigation.

Gender played a role in farmers' perceptions of irrigation access. Our results showed that most respondents (61%) were males (Table 1). This means that males dominate agriculture in the study area. This dominance contributed to the perception that irrigation access is reserved for males compared to females. This perception stems from traditional gender roles in Ghanaian agriculture, where men possess superior access to resources, information, and decision-making authority and are seen as the primary decision-makers and landowners. Moreso, this facilitates male farmers' active participation in innovation processes and faster adoption of new practices. It further aligns with theory of planned behavior, where those with more influence over production decisions are more inclined to accept innovations relative to their counterparts. On the other hand, females have limited opportunities to access irrigation. It also means that females have other responsibilities of water collection, cooking, childcare, and housekeeping aside from farm activities compared to men. Comparatively, these females had less decision-making power and this influenced their perceptions of irrigation access. Mensah and Fosu-Mensah (2020) found that gender inequity exists in agriculture and rural areas, affecting females' access to productive resources, land, financial services, technologies, and decision making despite their significant roles.

Regarding education, 75% of the respondents had primary and secondary level of education (Table 1). This means that the respondents were literate. Literate farmers are more likely to be exposed to extension materials, media, and training programs, positioning them as potential early adopters who can influence others within their social networks. Therefore, farmers' literacy influenced their perceptions of irrigation access. It also means that farmers with higher levels of education are more likely to be aware of and understand the benefits of irrigation. They can also use and maintain irrigation systems well. Literacy among farmers supports the diffusion of innovations theory by enabling informed decision-making and encouraging broader adoption within the farming community. Moges and Taye (2017), found that educational level of farmers had a positive and significant association with their perceptions.

The results have shown that nearly 70% of the respondents obtained about Gh₵3000 (USD197.59) from their farms each season (Table 1). This shows that farmers obtained low incomes from farm activities, which is insufficient for irrigation access investment. In line with the diffusion of innovation theory, farmers with limited financial resources may be less likely to adopt irrigation due to the high initial cost. Low-income farmers may prioritize short-term survival over long-term benefits, making them more cautious or slower in the innovation-decision process. Therefore, financial constraints can hinder the diffusion of innovations among farmers, placing them among the late adopters or laggards in the adoption curve. On the other hand, respondents with higher incomes may be more likely to have a positive perception of irrigation access. These farmers could afford to have access to good irrigation technologies and use irrigation more. They may have a more positive experience with irrigation access because they can afford repair and maintenance costs. Farmers' higher farm income was associated positively with access to irrigation (Akudugu et al., 2021; Riaz, 2023).

With regards to household size, our results have shown that the respondents (71%) had an average household size of 5 persons (Table 1). This means that household size can contribute to labor on farms for the repair and maintenance of irrigation systems. It further implies that larger households may have more hands available to assist with the labor-intensive tasks associated with irrigation system upkeep. Conversely, smaller households may struggle to keep up with the demands of irrigation system repair and maintenance. This could negatively influence farmers' perception of access to irrigation. In relation to subjective norms and perceived behavioral control, farming decisions may be influenced by the expectations, needs, and support of family members, shaping farmer's perception of social pressure to adopt or reject certain practices. Additionally, a larger household may provide more labor resources, potentially increasing farmer's perceived control over implementing new technologies. Therefore, household size can significantly affect a farmer's intention and ability to adopt innovations or engage in planned behavior. This result corroborates the findings of Aryal (2021) and Kirui (2019), who revealed that households with more persons are more likely to perceive irrigation as a viable option.

Table 1: Respondents' Household Factors

Socio-demography	Category	Frequency	Percentage (%)
Gender	Male	173	61
	Female	109	39
Age (Years)	18-29	12	4
	30-39	45	16
	40-49	133	47
	50-59	66	24
	60-69	22	8
	Above 69	4	1
Education level	No formal Education	53	19
	Primary/Basic	86	31
	Secondary	124	44
	Tertiary	19	7
Household income (GH₵)	< 1000	33	12
	1000-1499	28	10
	1500-1999	26	9
	2000-2499	55	20
	2500-2999	61	22

	Above 2999	79	28
Household size (Numbers)	1	2	1
	2	5	2
	3	25	9
	4	45	16
	5	83	29
	6	73	26
	7	10	4
	More than 7	39	13

(Source: Field Survey, 2024)

Our results have shown that 76% of the respondents did not own farmlands (Table 2). It means that lack of ownership of farmland may affect farmers' perceptions of irrigation access. It further implies that those farmers without land ownership right might view irrigation as less relevant or less accessible compared to landowners. Moreso, farmers without land ownership may feel they have limited control or influence over decisions regarding irrigation access and long-term land improvements, leading to a reduced intention to adopt such practices. Additionally, their attitude toward irrigation may be less favorable due to the insecurity associated with farming on non-owned land, and they may not perceive strong subjective norms encouraging investment in irrigation. However, farmers with secure land tenure are more likely to have a positive view of irrigation access. Therefore, a lack of land ownership undermines key components of the theory of planned behavior, resulting in lower motivation and intention to engage in irrigation. This result agrees with the findings of Koirala et al. (20169 and Mazhar et al. (2023), who found that farmers who do not own farmland are less likely to invest in land improvement and in irrigation.

Our results have shown that half (50%) of the respondents operated on farm sizes of less than 5 acres, mostly at different locations (Table 2). It means that the size of farmlands can influence farmers' perceptions of irrigation access. Farmers with smaller plots of land may not be interested in irrigation access due to the high initial costs of implementation. Moreso, farmers with smaller plots of farmland may view irrigation access as a struggle and may not recover the initial investment costs of irrigation. According to the diffusion of innovation theory, for farmers with small landholdings, the perceived benefits of adopting new technologies like irrigation may seem limited if the scale of production is too small to justify the investment. Additionally, such farmers may be more risk-averse and cautious to adopt innovations, which might place them among the late majority or laggards in the adoption curve. Thus, small farm size can hinder both the perception of value and the actual ability to adopt agricultural innovations. Asrat and Simane (2018) found that farm size influences farmers' decisions to implement technologies such as irrigation.

Regarding experience, the respondents (59%) had farmed for about 24 years in the study area (Table 2). It means that the respondents had a significant amount of experience in agriculture and related irrigation constraints. This level of experience farmers have could mean a deep understanding of farming practices and potential challenges that may arise. With these years of farming experience, the respondents may be well-equipped to make informed decisions about irrigation access. In addition, extensive farming experience might likely enhance farmers' confidence in their ability to assess and manage irrigation practices, thereby strengthening their perceived behavioral control. Moreover, such experience might contribute to a more informed and realistic attitude toward the benefits and challenges of irrigation access. These experienced farmers might also be influenced by subjective norms shaped through long-term social interactions within their farming communities. Therefore, farmers' extensive experience aligns with the theory of planned behavior where experience influenced decision-making and intention to adopt or engage in irrigation. Baley et al. (2017) found in the Central Rift Valley of Ethiopia that farmers' years of farming experience may enable them to make informed decisions about irrigation access.

Table 2: Respondents' Farm Size, Ownership Status and Experience

Socio-demography	Category	Frequency	Percentage (%)
Farmland ownership status	Owned	69	24
	Not owned	213	76
Farm size (Acreage)	< 5	140	50
	5-9	58	21
	10-14	38	13
	15-19	25	9
	More than 20	21	7
Experience (Years in farming)	< 5 years	13	5
	5-14	74	27
	15-24	89	32
	25-34	69	24
	35-44	33	12

(Source: Field Survey, 2024)

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Smallholder Farmers' Irrigation Water Sources

To better understand why farmers were unable to implement irrigation, we asked the respondents about what water sources were available and accessible to them within a desirable distance. Our results have shown that the respondents (68%) did not have accessible irrigation water sources within a suitable distance (Figure 2). It means that the lack of proximity to water sources made the respondents' perceived irrigation access difficult. These respondents further expressed concern over the additional time and resources needed to transport water to their fields. They mentioned how they had to rely on inconsistent rainfall patterns, resulting in lower quality crops and reduced profits. Furthermore, the lack of access to water sources has also hindered the farmers' ability to expand their operations or grow certain types of crops that require more consistent irrigation. Groundwater was also not within their reach because the water table is so low, making them view irrigation access as a difficult task. Accessing ground water needs a higher and sophisticated technology, which is often costly. Therefore, they view irrigation access as a costly venture.

However, those respondents (32%) who used irrigation on their farms accessed irrigation water from Rivers and streams. They mentioned that using rivers and streams was more feasible because of its proximity to their farms. Additionally, they noted that rivers and streams provided a consistent water supply compared to other sources. Despite the challenges faced by many farmers in accessing adequate water sources for irrigation, those utilizing rivers and streams have seen increased success in their farming endeavors. This highlights the importance and the positive perception of irrigation access due to the proximity and availability of water sources to farms.

According to the respondents, there were no reservoirs or canals in their communities. This lack of infrastructure means that the respondents had to rely on other water sources, like wells. However, the attempt to use wells often failed during periods of drought or when groundwater levels are low. These respondents viewed the absence of reservoirs and canals as a limitation to irrigation water access. Amankwaa-Yeboah et al. (2023) found that the possibility for farmers to use irrigation was limited because of the lack of reservoirs and canals.

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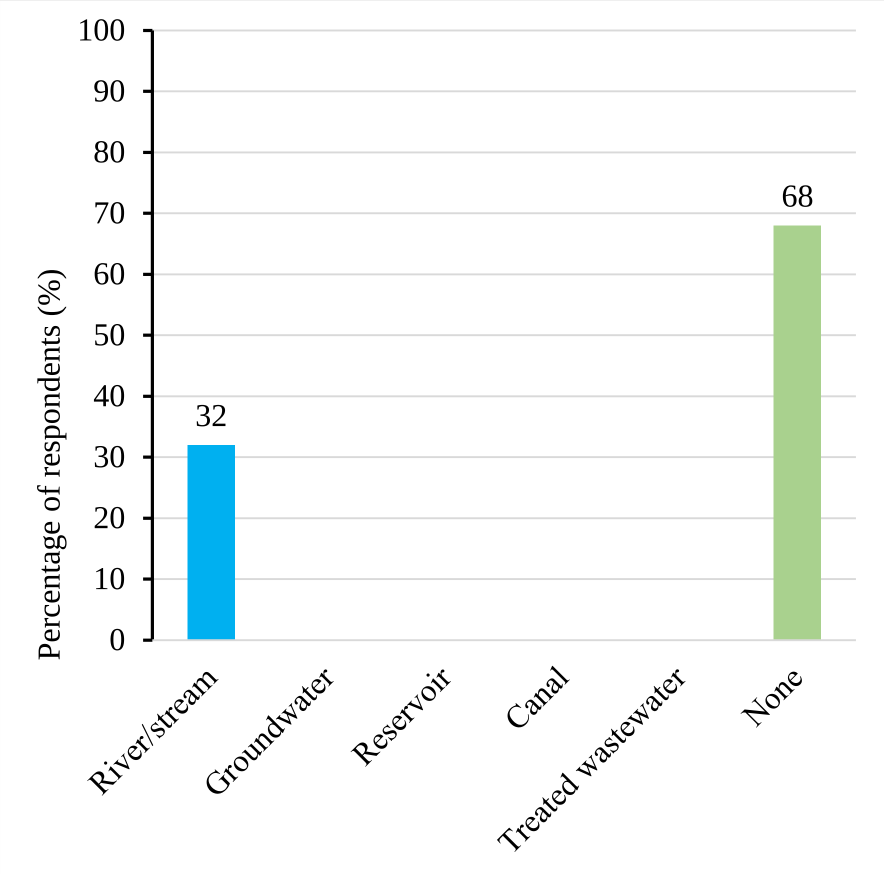

Figure 2: Available Irrigation Water Sources in the Study Area
(Source: Field Survey, 2024) n = 282

Smallholder Farmers' Irrigation Methods

Regarding the irrigation methods that farmers use in the study communities, we asked the responding irrigators what irrigation methods they rely on most. We provided a range of responses for all irrigators to choose from, as shown in figure 2. Our results have shown that respondents (71%) used gravity irrigation more on their farms (Figure 3). This shows that gravity irrigation is simple and cost-effective. It is well-suited to the natural sloping landscape of these farming communities. We then argued that farmers in areas with sloping land are more likely to rely on gravity irrigation due to its efficiency on such terrain. In addition, if farmers use gravity irrigation efficiently on sloping lands, it could result in significant savings for them. This will make it a practical choice for those farmers looking to maximize their income. Therefore, farmers using gravity irrigation may save on irrigation costs.

Our findings revealed that sprinkler irrigation was the next popular irrigation system the respondents (68%) used on their farms (Figure 3). It is an efficient and convenient method that saves them time and labor compared to the gravity method. Those respondents who use sprinklers see them as a flexible system as they are easily adjustable to the watering schedule based on weather conditions and crop needs.

Our survey found that 28% used furrow irrigation on their farms (Figure 3). This result is somewhat contrary to the common notion of furrow irrigation as a popular method among farmers due to its efficiency in delivering water directly to the root zone of crops. This technique involves creating small channels or furrows between crop rows, allowing water to flow and infiltrate the soil where it is needed most. The use of furrow irrigation can help conserve water and reduce runoff. Farmers who use furrow irrigation often cite the method's ability to minimize water waste as a key advantage. Additionally, it might help in preventing soil erosion by keeping water where it is needed most.

Regarding drip irrigation method, we found that only 2% mostly used (Figure 3). This is a more costly method compared to the others above. This may be the primary inhibiting factor for smallholders to rely heavily on these methods. Despite the higher cost, drip irrigation has been found to be more efficient in terms of water use and crop yield. However, for smallholders with low financial resources, the initial investment may be prohibitively costly. As a result, many farmers continue to use traditional irrigation methods, which are often less efficient in the long run.

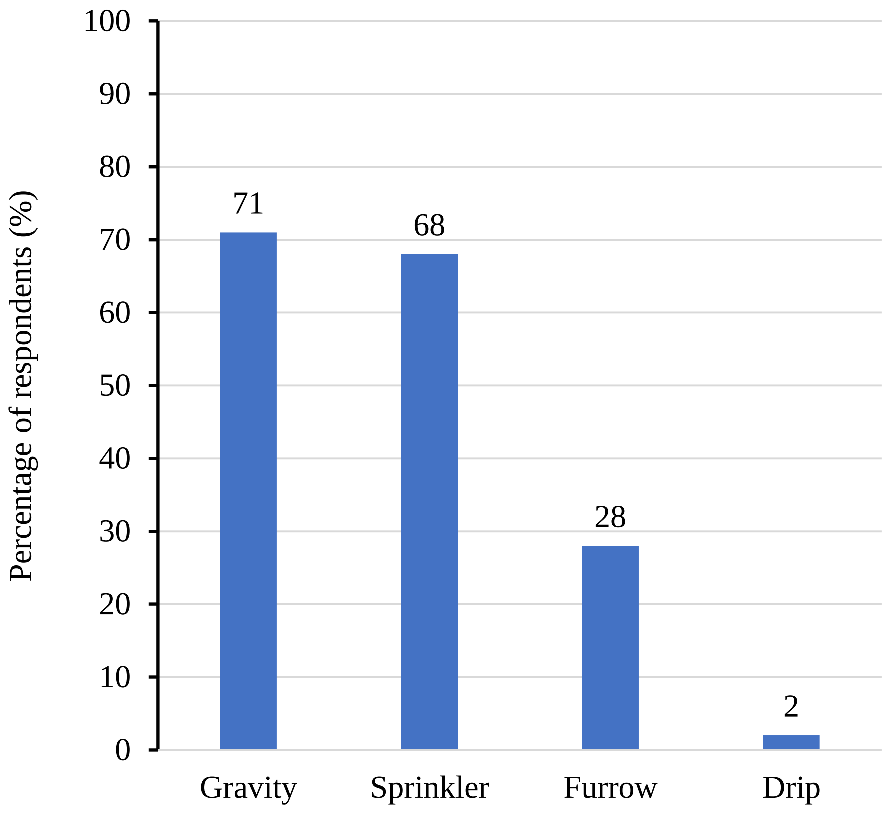

Figure 3: Irrigation Systems Farmers Use in the Study Area
(Source: Field Survey, 2024) n = 90

Smallholder Farmers' Irrigation Water Access

To understand whether smallholder farmers have access to sufficient irrigation water in the study area, the responding irrigators were further asked to choose from the following options: excellent, satisfactory, sometimes not reliable and very poor. We found that 68% irrigators did not have consistent and sufficient irrigation water access (Figure 4). This means that farmers might have experienced pipe leakages and siltation challenges in accessing reliable irrigation water, highlighting the need for technical support.

However, we found that 18% and 14% of the responding irrigators had satisfactory and excellent irrigation water access respectively on their farms. This means that the responding farmers were located near a reliable water source and had access to a reliable irrigation infrastructure. It also means that these respondents had invested in irrigation systems, which helped improve water access on their farms to some extent.

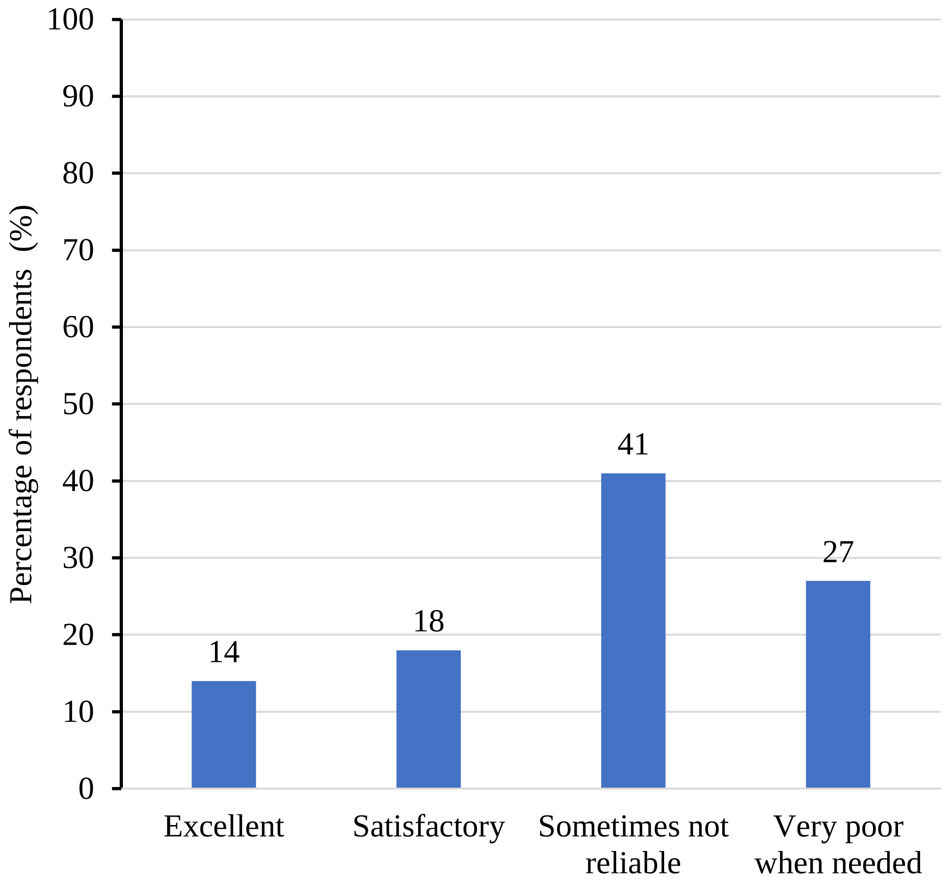

Figure 4: Smallholder Farmers' Irrigation Water Access
(Source: Field Survey, 2024) n = 90

Volume of Irrigation Water for Crop Production

We tried to verify with the responding irrigators, if the quantity of irrigation water was enough to grow their crops. We found that of the 90 responding irrigators, 61 of them representing 68% did not have sufficient water to grow their crops to their desired level (Figure 5). This means that a lack of irrigation water resulted in lower crop yields and decreased profits for many farmers. Some of them expressed frustration with the inconsistent availability of water because of the impact it had on their yield. Some respondents mentioned that they had to resort to rainfall to supplement their irrigation needs. Others had to reduce the scale of production, which means that water access became a pressing issue that cannot be ignored any longer. The impact of inadequate irrigation water on agriculture in the study area was clear, highlighting the urgent need for sustainable water management practices.

The remaining 29 responding irrigators, representing 32% reported having enough irrigation water on their farms. It means that these respondents were close to water sources and had installed irrigation infrastructure for irrigation water access. However, upon our further investigation, we discovered that these respondents sometimes lacked sufficient water due to outdated irrigation infrastructure, causing leaks and breaks in the system as mentioned earlier.

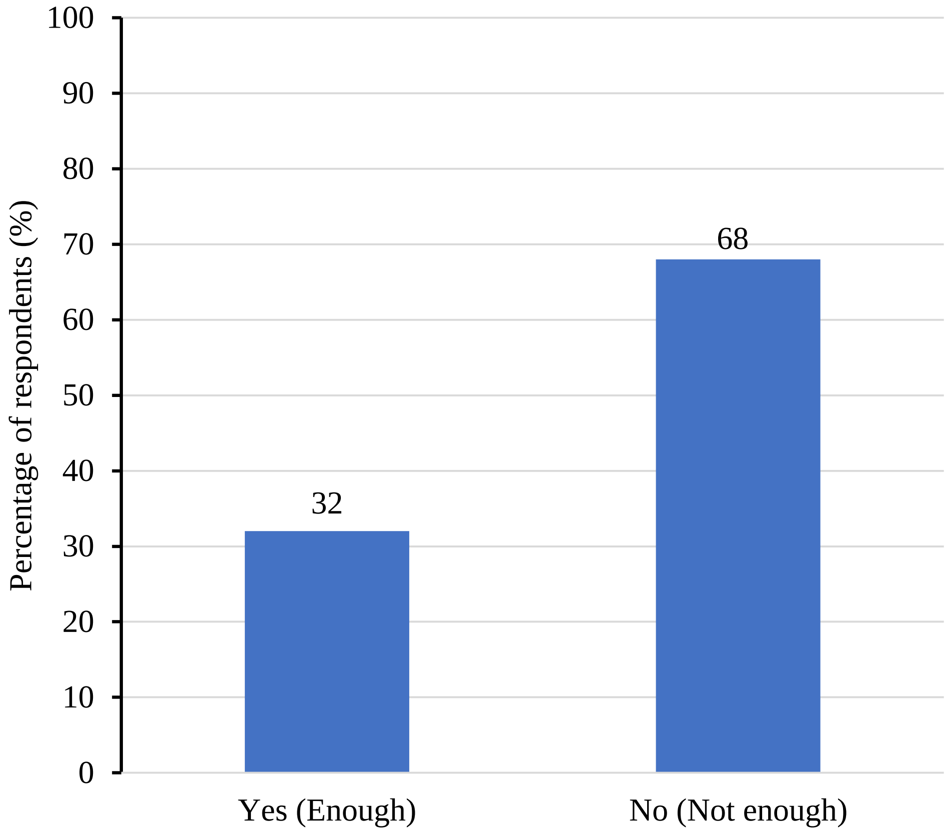

Figure 5: Satisfaction with Irrigation Water for Crops
(Source: Field Survey, 2024) n = 90

Smallholder Farmers' Reasons for Unreliable Water Access

In order to gain insight from farmers, our survey asked all the 90 respondents: "If water access was not always reliable, what were the main reasons for this lack of reliability?" We offered the following options for respondents to choose from: drought, leakage, inadequate infrastructure, water clogging/poor maintenance, farmlands obstructing canal routes, and water rights disputes.

We found that 74% chose inadequate infrastructure as the main reason for the unreliable irrigation water access (Figure 6). This means that farmers were unable to access the water they needed to irrigate their crops effectively. It also means that farmers needed irrigation infrastructure support for a reliable irrigation water access to make their productivity sustainable and become food secured.

Our results have shown that some respondents (59%) experienced water clogging and poor maintenance in their systems (Figure 6). This is believed to be one of the reasons for the unreliable irrigation water access in the study area. This means that the lack of proper drainage systems and routine maintenance checks contributed significantly to the water clogging. It also means that a lack of awareness among farmers about the importance of regular system maintenance was responsible for the water clogging in the system. Therefore, it means that farmers need education, regular checks and improved infrastructure for a more reliable irrigation water access.

We also found that 56% cited unpredictable weather patterns that led to drought conditions (Figure 6). It means that farmers must adapt their irrigation techniques and crop selection to withstand periods of drought. This highlights the need for investment support for farmers to access sustainable irrigation infrastructure to mitigate the effects of climate change on crop production.

The next reason for the unreliable water access among respondents was the obstruction of the canal route by farmlands. We found that about 55% of the respondents blamed neighboring farmlands for blocking canal routes to their farms (Figure 6). It means farmers find it difficult to access irrigation water. In addition, farmers were unable to properly water their crops. Obstruction of canal routes by farmlands highlights the need for better communication and cooperation between farmers in the study area. This could ensure that water access is maintained for all members of the community. Furthermore, this could mitigate conflicts and ensure sustainable water usage for everyone involved.

Another 54% of the respondents indicated leakages as the reason for the unreliable irrigation water access (Figure 6). It means that water pressure was inconsistent and affected their irrigation water distribution and access. This highlights the need for infrastructure improvements to ensure consistent and adequate irrigation water access for farmers. We then inferred that while leakages may be a factor in unreliable irrigation water access, it is also important to consider inadequate maintenance and outdated infrastructure. Moreover, focusing only on infrastructure improvements may not fully address the root causes of unreliable irrigation water access among farmers.

Our results have shown that some respondents (37%) experienced water rights disputes, generally related to irrigation water usage disagreements (Figure 6). The main issue reported was lack of access to water sources. It means that the respondents’ neighbors were diverting more water than their fair share, causing shortages for others downstream. In addition, others who used shared irrigation systems reported conflicts over the maintenance and repair costs. This also means that some respondents were not cooperating in maintenance and repair works.

Therefore, the water rights disputes highlighted the need for clear communication and fair distribution among farmers.

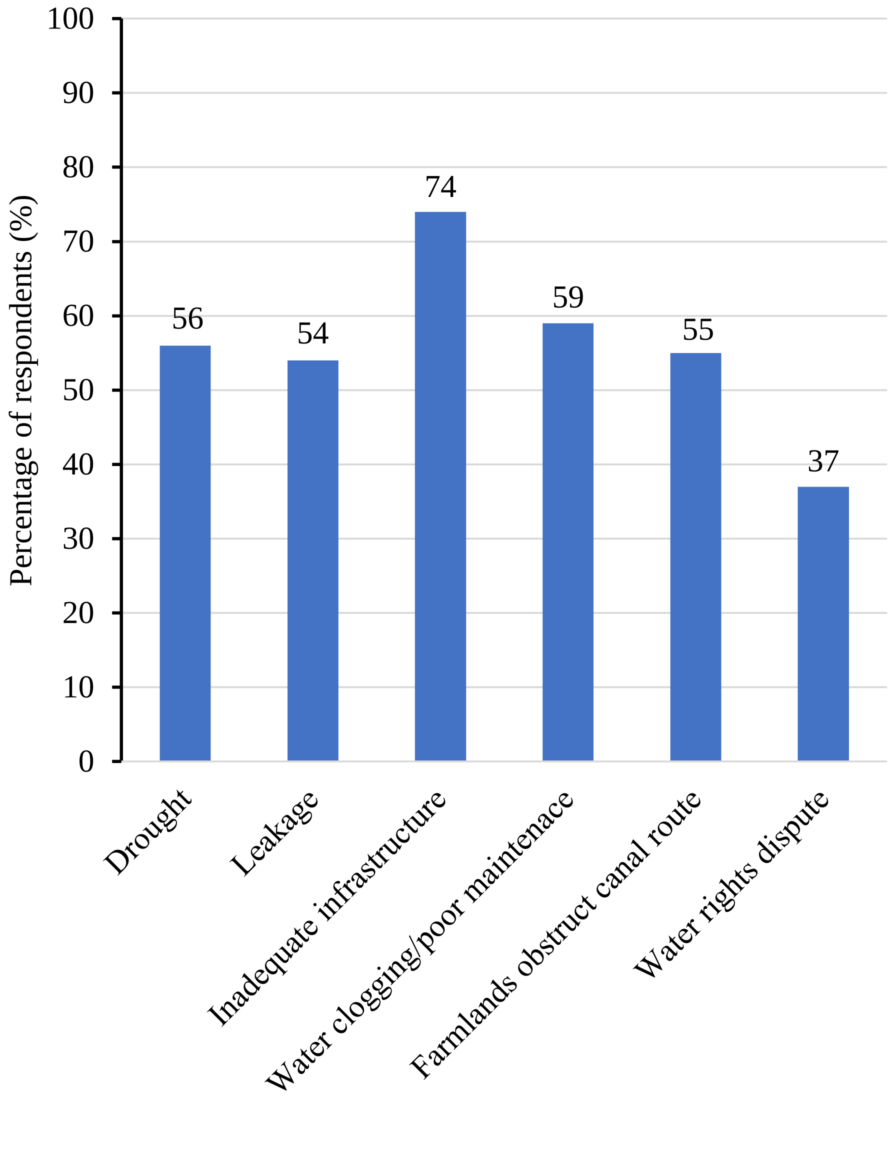

Figure 6: Reasons for Inconsistent Water Access
(Source: Field Survey, 2024) n = 90

Irrigation Water Access Reliability and Future Irrigation Services

Our survey further asked the respondents if irrigation water access reliability would affect their decision to rely more on irrigation services in the future. We found that 87% of the respondents agreed that reliable irrigation water access could affect their decision to rely more in the future on irrigation services (Figure 7). This means that the farmers recognized the importance of consistent access to irrigation water in their decision-making process. It also means that if farmers have a reliable and consistent water access, they would be encouraged to decide to irrigate even in the future. Reliable access to irrigation water could enhance farmers' perceived behavioral control, enabling them to use irrigation resources more effectively and, in turn, strengthening their intention to rely more on irrigation services.

However, 13% of them said consistent water access alone would not motivate them to irrigate. Instead, these respondents mentioned start-up capital, technical support, infrastructure, and market as reasons for increasing reliance on irrigation in the future. This means that if farmers have the required resources and support structures in place, their irrigation efforts are more likely to succeed. Conversely, it also implies that if farmers lack resources or these factors, they may be less motivated to consider irrigation in the future. This highlights the need for infrastructure and technology supports to improve water access for farmers. Hatch et al (2022) found that lack of access to credit support is a significant barrier for farmers in Nigeria to participate in irrigation.

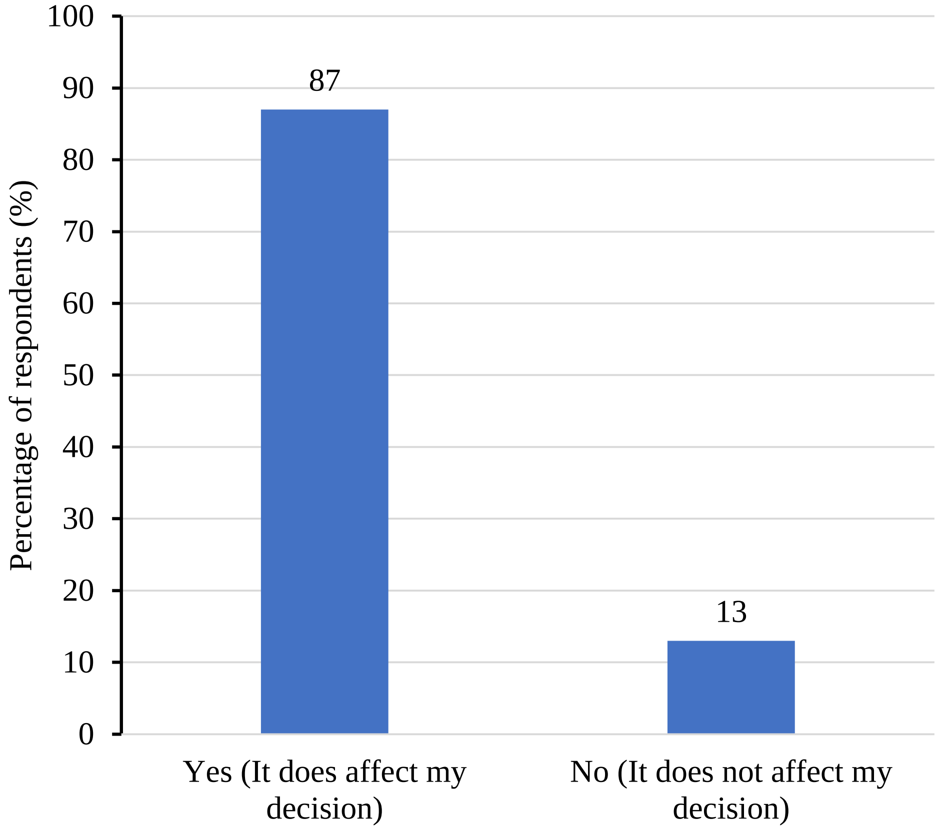

Figure 7: Smallholder Farmers' Irrigation Water Access and Decision Making
(Source: Field Survey, 2024) n = 90

Smallholder Farmers' Physical Challenges and Needs for Irrigation Access

We attempted to identify the needs of responding farmers with a Likert-scale question. From our preliminary field observation and literature review, we identified the following needs: No canals near farms, irrigation equipment support, secured waterway around farms, difficulty bringing water to farms, inadequate irrigation training, farmlands not near water sources, irrigation facilities maintenance, and inadequate irrigation information. Considering these physical challenges and needs, the respondents were asked to make applicable choices (Likert-scale questions), where 1 indicates strong disagreement and 5 being strong agreement (Figure 8).

We found that all responding farmers agreed and expressed that they needed irrigation equipment support from the government. It means that the responding farmers believed that irrigation equipment support is crucial for their farming operations to be successful. Otherwise, they would continue to struggle to keep their crops watered. In addition, government assistance will benefit individual operations and contribute to the overall success of agriculture in the area. This result is consistent with the findings of Kanza and Vitale (2015), who revealed that government assistance is essential for transforming agriculture.

The responding farmers also agreed to have a need for secured waterways (98%) around their farms (Figure 8). It means that during the rainy seasons, the respondents often experienced floods that destroyed their farms, crops, and farm infrastructure. They could prevent flood damages with well-developed waterways around their farms. Only 2% did not say if they experienced such flood damages or not and did not state if they needed waterways around their farms. It means that those farmers who did not specify whether they experienced flood damages or not may not have considered the importance of secured waterways in preventing future destruction. Also, it is possible that they might not fully recognized the impact that floods can have on their farms and livelihoods.

We found that most of the respondents (94%) appeared to have a strong agreement and high need for irrigation canals (Figure 8). It means that the responding farmers could not access enough irrigation water for their farms. They needed irrigation canals to support their farming activities. It also means that the lack of access to irrigation water is a common challenge among the surveyed communities. Only 6% disagreed and asserted that they do not need canals for their farm operations. It means that these respondents had access to irrigation water for their farms. They might likely have alternative sources of water for their crops, demonstrating a disparity in canal access among farmers.

About 68% of responding farmers found it difficult to bring water to their farms due to some obstacles on the way (Figure 8). Among the obstacles mentioned by these farmers, in connection with the previous section, were broken irrigation systems, lack of proper infrastructure, and long distances to water sources. They also mentioned leakages, water clogging and poor maintenance. It also means there is a need for investment and support in improving water access for farmers. It further means that more attention and resources need to be devoted to transfer water to farms despite the existence of these obstacles. About 27% of them disagreed and asserted that they faced no obstacles that could prevent them from bringing water to their farms. It means these responding farmers were close to water sources and can access irrigation water with ease. Only 4% did not tell us if they faced similar challenges of accessing water or not. It is possible that they did not experience any difficulties of water access or simply chose not to disclose this information.

The proximity to water sources seems to play a significant role in the financial aspects of farming for the respondents in our study (Figure 8). We found that responding farmers (66%) further agreed that their farmlands were not near water sources. It means, however, that farmers will incur a high cost of irrigation installation. They might spend more on high-capacity pumps and pipes. However, about 32% disagreed and asserted that their farms are nearer water sources. Conversely, it means it could save these farmers money on irrigation costs in the long run. Those who have access to water sources may also have the advantage of more sustainable farming practices. For these farmers, the proximity to water source could further provide a sense of security during times of drought or water scarcity.

We also found that responding farmers (65%) agreed that they did not have adequate irrigation training (Figure 8). It means that these farmers could not be motivated enough to invest in irrigation access. About 29% mentioned that they had irrigation training. On the contrary, it means these responding farmers could show more interest in irrigation access. Only 6% did not state if they had adequate irrigation training or not. It is possible that they did not receive any irrigation training that could motivate them to develop irrigation or simply chose not to disclose their view. Boora et al (2024) found that in Tabriz, Iran, training or agriculture education significantly increased the adoption of modern irrigation techniques.

Another 64% appeared to have had inadequate information on irrigation (Figure 8). It is possible that these farmers did not have sufficient access to local radio stations or extension services. Only 6% agreed that they accessed information on irrigation from local radio stations, television and from extension officers in the district. They also told us that they sometimes access irrigation information from annual workshops and seminars they attend. It means these farmers could perceive irrigation access to be crucial for their farm operations. 28% did not state if they access information on irrigation or not. Here, it is possible that these farmers did not receive any irrigation information or simply chose not to disclose their view. This result is consistent with the findings of Zongo et al. (2014) who determined that training and information dissemination in Burkina Faso promoted the adoption of irrigation technologies.

We further found that some responding farmers (44%) agreed that they cannot maintain irrigation facilities. It means these farmers did not have the technical expertise, knowledge, and skills about irrigation installation, maintenance and repair. However, 37% agreed that they can maintain irrigation facilities. Conversely, it means these farmers received training from the agriculture extension services. Only 18% did not state if they could maintain irrigation facilities on their farms or not. it is possible that these farmers did not receive any irrigation training or simply chose not to disclose their view.

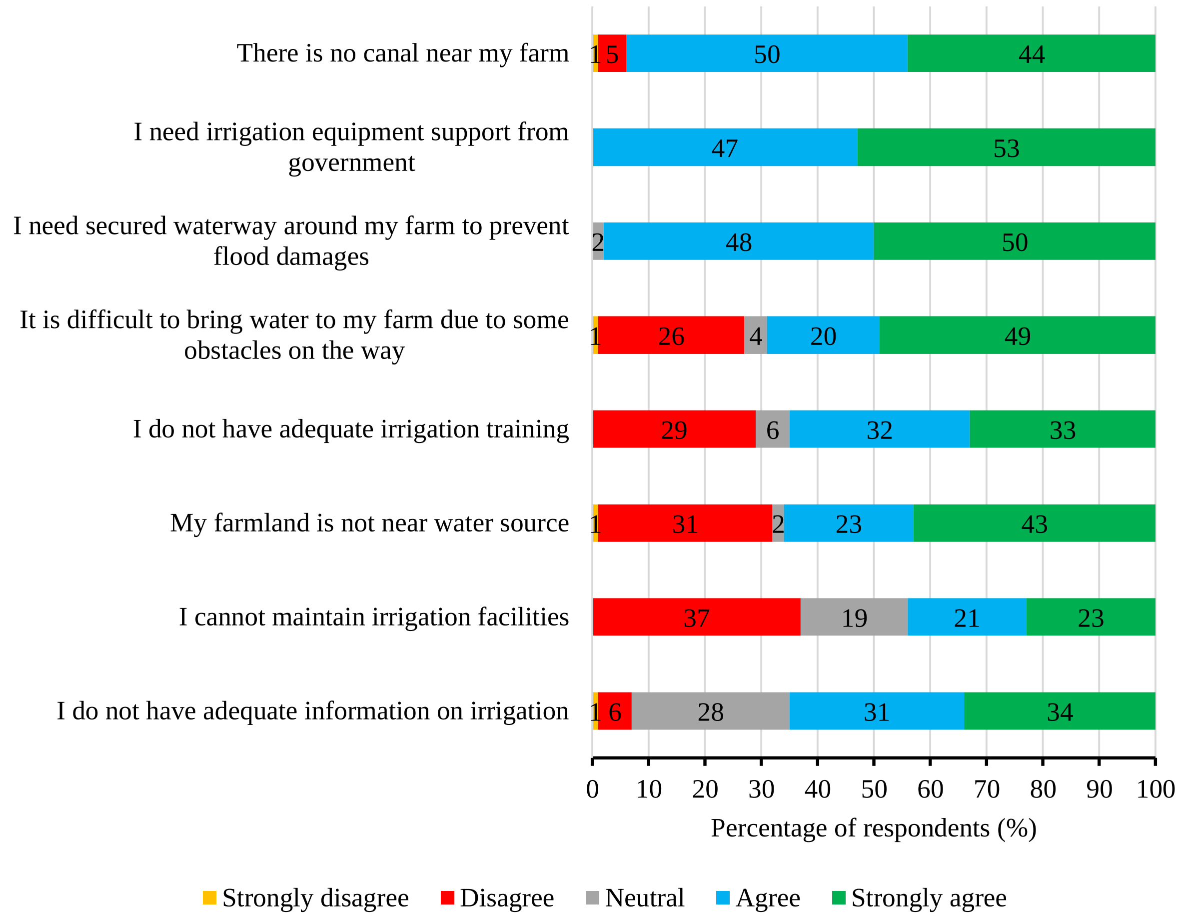

Figure 8: Smallholder Farmers' Physical Challenges and Needs
(Source: Field Survey, 2024)

Smallholder Farmers' Financial Challenges and Needs for Irrigation Access

In another Likert-scale question, we tried to understand the financial challenges smallholder farmers faced in irrigation water access. This question was based on the level of agreement among the respondents, where 1 indicates strong disagreement and 5 indicates strong agreement. The following options were presented: (1) Cost of connecting irrigation ditch is high; (2) Energy/electricity cost for pumping water is high; (3) Canal and pump maintenance costs are high; (4) I need credit support for irrigation; (5) I do not have enough capital to adopt irrigation; and (6) Irrigation requires additional maintenance cost.

The result shows that about 93% of the respondents agreed or strongly agreed that the cost of connecting irrigation ditches was high (Figure 9). It means the responding farmers need government subsidies or innovative technology, which could help make their investment more feasible. In terms of energy/electricity cost for pumping water, the result showed that almost 90% agreed or strongly agreed. This means that farmers are also concerned about the ongoing operational costs associated with irrigation. This highlights the need for farmers to explore renewable energy sources or use energy-saving technologies to reduce these costs in the long run. Li and Wang (2025) demonstrated that in southern Punjab, Pakistan, the implementation of irrigation systems was made difficult by high installation costs.

Other cost-related factors the respondents (88%) agreed or strongly agreed on were high canal and pump maintenance costs (Figure 9). It means that the responding farmers are aware of the additional expenses involved in maintaining irrigation infrastructure and equipment. In order to make irrigation more cost-effective, farmers need to invest in regular maintenance of their canals and pumps.

Regarding the need for credit support for irrigation, 98% agreed or strongly agreed (Figure 9). Another 95% agreed or strongly agreed and asserted that they did not have enough capital to adopt irrigation. In connection with our discussion in the previous section, 89% agreed or strongly agreed and blamed the fact that irrigation requires additional maintenance cost.

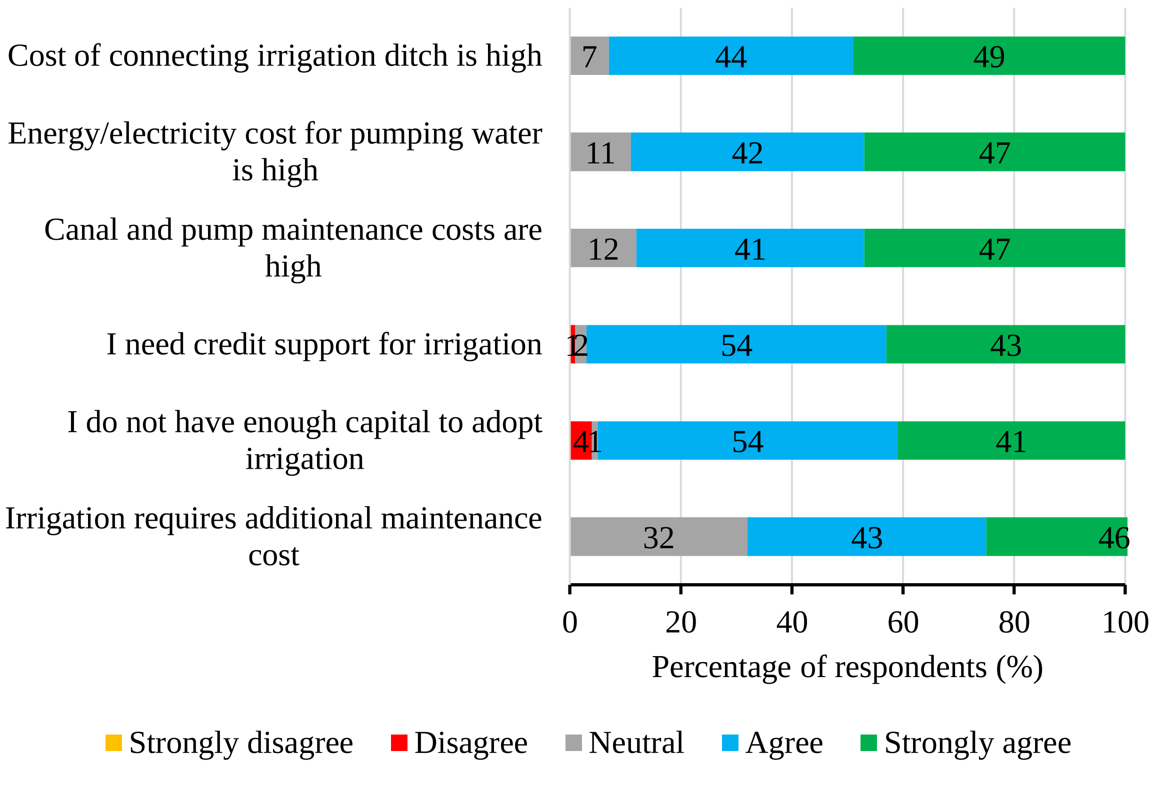

Figure 9: Smallholder Farmers' Financial Challenges and Needs
(Source: Field Survey, 2024)

Farmers' View of Irrigation Merits/Demerits

In another Likert-scale question, we tried to understand respondents' perceptions about irrigation benefits (Figure 10). This question was based on the level of agreement among the respondents, where 1 indicates strong disagreement and 5 indicates strong agreement. The following options were presented: (1) It reduces risks of drought; (2) It improves yield; (3) It contributes to business growth; (4) It reduces labor cost; (5) It creates jobs; (6) It controls weeds in rice fields; (7) It controls pests and diseases in rice fields.

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The results show that all respondents agreed or strongly agreed that irrigation reduces risks of drought (Figure 10). All respondents agreed (29%) or strongly agreed (71%) that irrigation improves yield. Regarding the benefit of business growth, the respondents agreed (55%) or strongly agreed (44%). In terms of labor cost, the results show that the respondents agreed (54%) and strongly agreed (37%). Regarding job creation, all respondents agreed (59%) or strongly agreed (49%). Regarding weed control by irrigation, the respondents agreed (37%) or strongly agreed (40%). Similarly, the respondents agreed (50%) and strongly agreed (31%) that irrigation controls pests and diseases in rice fields.

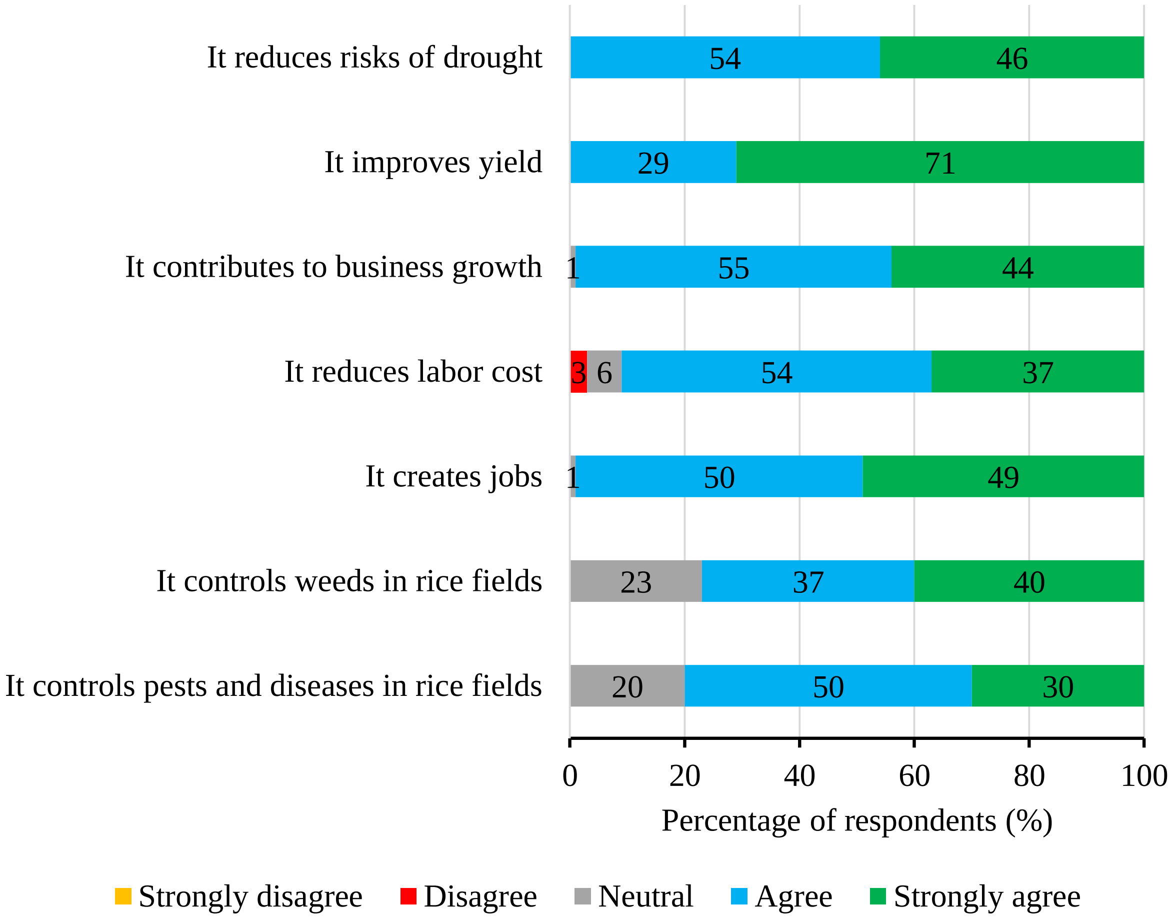

Figure 10: Farmers' View of Irrigation Merits/Demerits
(Source: Field Survey, 2024)

A Correlation Analysis on Factors Influencing Farmers' Perceptions

We then correlated the survey results with farmers' socio-demographic characteristics (Table 3). The results showed that gender, education, and household income were statistically significant and positively correlated with farmers' perceptions of irrigation access at $p < 0.01$, $p < 0.05$, and $p < 0.01$, respectively. The rate of irrigation access perceptions among farmers are likely to increase by 0.939 units as their income levels are increased by 1 unit. It means that high income could make farmers have a positive view of investing in new technologies like drip irrigation, pumps, pipelines, and infrastructure maintenance and may buy or lease land in places with easier access to water sources.

Education positively influenced farmers' perceptions of irrigation access at $p < 0.05$ significant level. This means that a unit increase in farmers' education level will result in 0.319 unit increase in the rate of their perception of irrigation access. It means that educated farmers could have the knowledge, skills, and resources they need to understand and use irrigation more effectively. In addition, educated farmers could negotiate bureaucratic processes well to have access to irrigation resources and may be more willing to experiment with new technologies. They are more likely to participate in community or cooperative projects aimed at improving irrigation access for everyone.

Regarding gender, a unit increase in female farmers will lead to a 2.284 unit increase in the rate of female farmers' perceptions of irrigation access. It means that though custom does not encourage land ownership by female farmers as compared to their male counterparts, ownership right could influence female's perceptions of irrigation decisions and access. Educated females with financial resources could advocate for their rights, implement irrigation practices, and lead community irrigation projects. They could push for legislation that gives them equal access to irrigation.

Table 3: Factors Influencing Farmers' Perceptions of Irrigation Access

Variables	Coef.	St. Err.	t-value	p-value	[95%] Conf	[Interval]
Gender	2.284	0.387	5.90	0.001***	1.525	3.043
Marital status	0.361	0.337	1.07	0.284	−0.299	1.022
Educational level	0.319	0.153	2.09	0.037**	0.019	0.619
Age (years)	−0.021	0.019	−1.14	0.256	−0.059	0.016
Farmland ownership	0.306	0.287	1.06	0.287	−0.257	0.869
Farm size (acre)	−0.024	0.044	−0.55	0.582	−0.111	0.063
Household income	0.939	0.124	7.55	0.001***	0.695	1.182
Household size	−0.010	0.093	−0.11	0.913	−0.193	0.173
Constant	−6.857	0.911	−7.53	0.001***	−8.643	−5.071
Number of observations	= 282					
Pseudo r-squared	= 0.652					
Chi-square	= 230.183					
Prob > chi^2	= 0.001					

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ denotes significance levels.

CONCLUSION AND RECOMMENDATIONS

This study examined smallholder farmers' perceptions of irrigation access in Ghana's South and North Tongu districts. Several factors including physical and financial constraints were identified. The socio-demographic characteristics showed that responding farmers depended on farm incomes that were insufficient for them to further invest in irrigation access. Customarily female farmers had less decision-making power, which influenced their perceptions of irrigation access. The theory of planned behavior, where those with more influence over production decisions are more inclined to accept innovations relative to their counterparts, confirmed this phenomenon. The responding farmers were literate and in connection with the diffusion of innovations theory, were able to make informed decision regarding irrigation access. However, financial constraints were blamed for their inability to access irrigation. Farmers with limited financial resources were unable to access irrigation due to its high initial cost. Low-income farmers prioritized short-term survival over long-term benefits, which made them more cautious and slower in the innovation-decision process. Therefore, financial constraints hindered the diffusion of innovations among farmers and placed them among the late adopters or laggards in the adoption curve.

A lack of access to irrigation water is a common challenge among the surveyed communities. Therefore, responding farmers expressed the need for canals (94%) development for easy access to water, irrigation equipment supports (100%), and secured waterways (98%) to prevent flood damages. Aside from these physical challenges, the respondents also encountered financial constraints, such as the cost of maintenance (89%), energy/electricity (89%) and irrigation ditch construction (93%). Respondents further blamed inadequate credit (97%) supports from government for the lack of irrigation access. In line with the diffusion of innovations theory, irrigation systems access depended on access to resources, perceived advantages, and support structures. The fact that 97% of respondents cited inadequate government credit support as a barrier reflects a critical lack of enabling conditions that was needed for adoption. With a lack of financial assistance or credit support, potential adopters, especially in resource-constrained settings, were unable to invest in irrigation infrastructure. Consequently, the diffusion process was slowed and the gap between innovators and late adopters became wider.

Most of the respondents did not have access to water sources within a desirable distance, and the low water table made accessing groundwater difficult. Those who were able to implement irrigation primarily sourced water from rivers and streams, highlighting the importance of proximity to water sources for successful irrigation practices. To increase irrigation adoption among farmers, efforts should be made to improve access to water sources and provide support for implementing irrigation technology. In connection with education level or literacy, all responding farmers were positive that irrigation can improve yield, food security, contribute to business growth, create jobs, and mitigate drought effects. A positive and statistically significant correlation exist between gender, education, household income and farmers' irrigation access.

Authors' Contributions:

This article is related to a thesis chapter by T.M.K. (the main author) at the University of Tsukuba, Japan, involving contributions from all five authors. T.M.K. developed the methodology, A.A.E. co-supervised, and edited the article with A.E.J. N.J.A. contributed to the theoretical framework, and N.M.G. contributed to data curation and review. All authors endorsed the final version of the manuscript.

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