International Journal of
Environmental Science
(IJES)

Examining Smallholder Farmers' Needs for Irrigated Crop Production: Insights from South Tongu District, Ghana

Tamekloe Michael Kossivi, Abiemo Edem Jerome and Niangue Josephine Andrea

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.8, Issue 1, No.3. pp 44 - 76, 2025

www.iprjb.org

Examining Smallholder Farmers' Needs for Irrigated Crop Production: Insights from South Tongu District, Ghana

Tamekloe Michael Kossivi[1*]
[*1]Graduate School of Science and Technology, University of Tsukuba, Japan

Abiemo Edem Jerome[2]
[2]School of Agriculture, Food and Ecosystem Sciences, the University of Melbourne, Australia

Niangue Josephine Andrea[3]
[3]Graduate School of Global Environmental Studies, Sophia University, Japan

Article History

Received 8th April 2025

Received in Revised Form 9th May 2025

Accepted 12th June 2025

How to cite in APA format:

Tamekloe, M. K., Abiemo, E. J., & Niangue, J. A. (2025). Examining Smallholder Farmers' Needs for Irrigated Crop Production: Insights from South Tongu District, Ghana. *International Journal of Environmental Sciences*, *8*(1), 44–76. https://doi.org/10.47604/ijes.3389

Abstract

Purpose: Research indicates that having irrigation water sources near farms can reduce infrastructure costs, improve farmers' productivity and income, and foster rural development. On average, farmers cultivate three plots in different areas due to land availability, affordability, and proximity to these water sources. However, in the South Tongu District, farms in water catchment areas are located upstream, which makes accessing irrigation water difficult. Attempting to draw water from a neighbor's farm can lead to conflicts. Given these challenges, it is essential to examine the needs of farmers and their access to irrigation resources. This paper examines smallholder farmers' needs for irrigated crop production in the South Tongu District of Ghana.

Methodology: A structured questionnaire survey was randomly administered among 120 smallholder farmers from April to May 2023 in six purposively sampled potential irrigation communities. The survey questions focused on farmers' needs and access to irrigation water sources. Our study is further rooted in utility maximization and risk aversion theories to understand farmers' choices with lower uncertainty, potential losses, and the option that provides them with the greatest satisfaction. The data were analyzed using SPSS and Excel.

Findings: We found that the district has fertile arable lands and abundant water sources. However, farmers expressed concern that farms are not close enough to these water sources, making it difficult to irrigate their crops. Almost all responding farmers (98%) were located far from available streams and the spillage from the Avu Lagoon (75%). About 67% said the Lower Volta River was not near their farm. Another 57% found that the Tordzi River was not nearby, and they cannot afford the cost of irrigation installation. Even those farms near water sources relied on rainfall (78%), indicating the need for infrastructure support. Responding farmers indicated a strong need for credit support to invest in irrigation technologies. About 74% requested canal development, while 71% sought support for irrigation equipment. Additionally, 64% needed technical support, and 54% requested general extension assistance for irrigation practices.

Unique Contribution to Theory, Practice, and Policy: This study contributes to making farmers rational and cautious actors towards resource allocation for improved irrigation benefits. The findings will help policy to tailor interventions based on farmers' socio-economic growth and psychological realities. Moreover, the findings will contribute to the development of policies and support systems to improve farmers' satisfaction with irrigation practices.

Keywords: *Smallholder Farmers, Crop Production, Irrigation, Farmers' Needs*

JEL Codes of Classification: *O33, Q00, Q13, Q14, Q16, Q25*

INTRODUCTION

In Sub-Saharan Africa, water scarcity resulting from climate change impacts and the lack of access to water sources for agriculture have become major concerns for smallholder farmers (Abegunde et al., 2019; Ofori et al., 2021). Past studies have shown that water sources are not close enough to farms, leading to an increase in irrigation infrastructure development costs for farmers (Falchetta et al., 2023; Siderius et al., 2024; Sun et al., 2021). Studies by Durga et al. (2024) and Pereira et al. (2023) indicate that farmers tend to encounter a lack of infrastructure and technologies to adequately manage water sources for agricultural production. Furthermore, Diallo et al. (2020) emphasized that smallholder farmers experienced climate change impacts on their crop production, resulting in increased susceptibility to food insecurity.

Additionally, utility maximization theory outlined why some farmers were unable to engage in irrigation (Ferrari-Toniolo et al., 2020; Pratiwi et al., 2022; Touch et al., 2024). The UMT can be applied to farmers' desire for irrigated crop production (Kemeze et al., 2020). In its application, farmers will aim to maximize their overall utility by selecting agricultural practices that yield the most significant benefits (Schulze et al., 2024). Therefore, with the existing constraints of climate change in the forms of unpredictable rainfall and rising temperatures, farmers may choose to adopt irrigation to enhance crop yields, ensure food security, and increase their incomes (Touch et al., 2024; Umer et al., 2024). These farmers can mitigate the risks associated with water shortages and drought with greater satisfaction (Monteiro et al., 2024). However, in the South Tongu District of Ghana, where this study is focused, farmers tend to rely more on rain-fed agriculture (Baffour-Atta et al., 2025; Martey et al., 2025). This reliance has resulted in low productivity and yields due to limited access to irrigation water sources (Acheampong et al., 2018; Nchanji et al., 2023).

In Ghana, particularly in the South Tongu District, smallholder farmers are struggling for water to irrigate their crops (Ankrah et al., 2023; Dinko & Nyantakyi-Frimpong, 2023). Meanwhile, South Tongu is an agricultural hub, and irrigation is critical for crop production, especially during the dry season. The closeness of farms to the Volta River Basin offers great irrigation potential (Liersch et al., 2023; Smits et al., 2024). However, those farmers upstream of the basin raised worries about the long-term viability of irrigated crop production (Yiridomoh et al., 2023). Many farmers were unable to afford the cost of lifting water from water sources to their farms (Balana & Akudugu, 2023; Guba et al., 2023; Namara et al., 2014). Instead, they relied on rain-fed crop production (Klutse et al., 2021; Otokunor et al., 2023; Yeleliere et al., 2023). Nevertheless, Bernoulli's (1738) risk aversion theory emphasized that irrigation could provide a stable water supply, improve yield, ensure food security, and provide stable income for farmers (Mupaso et al., 2024). Farmers could further mitigate production risks and enhance their resilience if irrigation is used as a rational choice for long-term and economic security (Ahmadi et al., 2025; Elmahdi, 2024). Despite the positive contributions of irrigation, farmers still rely on rainfall, especially in the South Tongu district (Mensah et al., 2018; Sarku, 2023).

According to Bernoulli's (1738) risk aversion theory, individuals prefer choices with lower uncertainty and potential losses, even if riskier alternatives offer higher potential gains (Lejarraga & Hertwig, 2022). Most people dislike ambiguity, and when faced with a tough decision, they will generally go for the "safer," risk-free option (Begho & Balcombe, 2023; Levy et al., 2010). Therefore, farmers who face climate variability and financial constraints might exhibit risk-averse behavior and become hesitant to adopt irrigation (Katic & Ellis, 2018; Tai et al., 2024). Additionally, inadequate technical support contributes to farmers' low irrigation adoption rate (Asfaw & Mekonen, 2024; Serote et al., 2023; Tesfaye et al., 2021). As a result, these farmers are unable to minimize the risks associated with rainfall dependency (Bedo et al., 2024; Datta & Behera, 2024).

The South Tongu District is endowed with rich water sources such as rivers, streams, and groundwater, which farmers can use for irrigated crop production (Agodzo et al., 2023; Nikoi & Alorbu, 2023). However, some studies have shown that farmers failed to utilize available water sources for agricultural production, unlike in other regions where irrigation thrived (Bessah et al., 2022; Suri, 2019; Tuffour et al., 2023). Farmers continued to rely more on rainfalls with low productivity and yields (Azumah et al., 2020; Klutse et al., 2021). It is critical to demonstrate through studies that the availability of water sources in South Tongu could contribute to long-term irrigated crop production. Past studies demonstrate that the success of irrigated crop production depends heavily on water availability, access, infrastructure, and energy/electricity (Bazzana et al., 2023; Danish et al., 2017; Karimi et al., 2024; Manasseh et al., 2025; Yang et al., 2023). Additionally, irrigation equipment availability and cost could have a substantial impact on irrigated crop production (Ullah et al., 2023; Umer et al., 2024). Similarly, farmers' low irrigated crop production is attributed to high irrigation equipment costs and inadequate irrigation training (Abdallah et al., 2023; Akrofi et al., 2019; Bowan et al., 2023; Dinye & Ayitio, 2013). For these reasons, some studies have shown that indigenous knowledge and skills can be mobilized by the government in the development of rural irrigation infrastructure to help farmers minimize costs (Chanza, 2018; Makate, 2020). According to Angom & Viswanathan (2023), farmers experienced improved productivity, yield, and income due to irrigation infrastructure access and technical and financial support from government projects.

Problem Statement

The abundant water sources of the South Tongu District could sustain irrigation farming. However, farmers still rely on rain-fed agriculture for various reasons. Even farmers located upstream appear not to draw water from nearby sources for irrigation. Some are reluctant to invest in irrigation water storage facilities or reservoirs. Only a few farmers utilize available water sources for irrigation. The factors contributing to the low level of irrigated crop production among farmers in South Tongu remain unclear and insufficiently explained. Moreover, theoretical studies linking utility maximization and risk aversion theories to farmers' decisions regarding irrigated crop production are limited. It is crucial to understand the real needs of farmers to be able to build their capacity to drift away from rain-fed production to irrigation systems. Considering success stories of irrigation in other countries, it is possible to demonstrate that the available water sources in South Tongu could contribute to long-term irrigated crop production. This study, therefore, examines smallholder farmers' needs for irrigated crop production in the South Tongu District of Ghana. The findings will help policymakers and stakeholders to make informed decisions in addressing water management needs for farming communities to enhance productivity, yield, and livelihoods. Moreover, it could encourage support systems to efficiently use water, reduce uncertainty, and improve farmers' satisfaction and productivity through irrigated crop production. Additionally, the study will contribute to existing literature on theories in economics and agriculture production.

International Journal of Environmental Sciences
ISSN 2519-5549 (online)
Vol.8, Issue 1, No.3. pp 44 - 76, 2025

LITERATURE REVIEW

Theoretical Review

Utilities Maximization Theory

Bentham (1789) developed a theory of utility as a measure of pleasure derived from actions (Long, 2017), which Mill (1848) later elaborated by emphasizing individual utility in social and economic contexts (Hansson, 2022). Jevons (1871) and Menger (1871) independently introduced the concept of marginal utility, highlighting its role in individual decision-making and utility maximization within economic theory (Moscati, 2019). Walras (1874) further linked utility maximization to market equilibrium, laying the foundation for modern decision theory, which has since been expanded by contemporary economists through the use of mathematical models (Müller, 2021).

Utility maximization (UM) contributes to the understanding of human decision-making, particularly in modern economics, where individuals or households aim to maximize their satisfaction or utility (Loewenstein & Ubel, 2008). They do so while facing constraints such as limited income, resources, and risks (Raja & Alias, 2024). UM is a concept that is also used in agricultural economics to explain how farmers decide which irrigation system investments to make (Katic & Ellis, 2018). In Ghana, irrigation is an essential tool for increasing crop productivity and lowering risks because the agricultural sector is vulnerable to unpredictable rainfall patterns and droughts (Maleksaeidi et al., 2017). As illustrated in Figure 1 below, the utility maximization theory (UMT) is used in this study to explain how farmers make decisions regarding the adoption of irrigation systems on their farms (Sarku et al., 2020).

Ghanaian farmers, like those in other developing nations, are vulnerable to several climatic constraints (Antwi-Agyei et al., 2018). The most common climatic challenges are flood and drought (Gosling & Arnell, 2016). Irrigation can reduce these risks by ensuring a regular water supply, a critical factor in agricultural productivity (Faurès, 2013). UMT explains why farmers could be reluctant to invest in irrigation systems. Farmers often compare the installation, maintenance, and operation costs against the expected benefits, such as improved yields, reduced risk, and higher economic returns (DeJanvry et al., 1997). The utility function can be viewed as a relationship between an individual's preferences and the goods or services consumed, reflecting a trade-off between income, consumption, and risk mitigation (Frey & Stutzer, 2014). In the case of farmers, utility can be defined in terms of financial outcomes, satisfaction from reduced risks, improved yield, and food security (Diallo et al., 2020).

UMT can be applied to irrigation farming in Ghana, especially in the South Tongu district, where farmers mainly rely on rainfall, which renders them vulnerable to climate-related fluctuations (Antwi-Agyei et al., 2018). The use of UMT in this context could provide a more profound understanding of the factors affecting irrigation implementation among farmers (Sarku, 2023). For instance, a study by Smith and Ulu (2017) showed that risk aversion, financial considerations, technology accessibility, and markets were among the major factors affecting utility maximization choices among farmers.

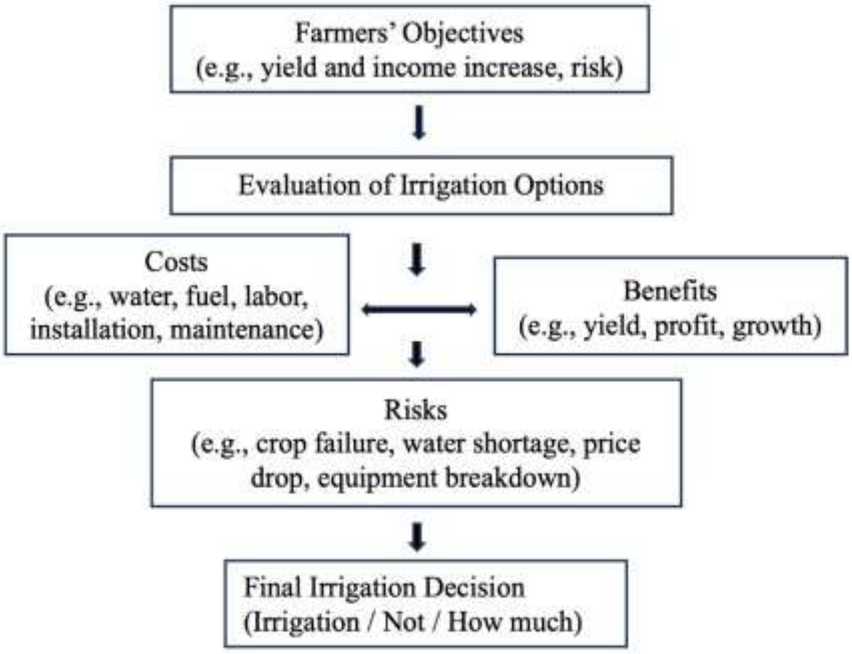

Figure 1: Farmers' Irrigation Decision Framework

Farmers behave in a way that makes sense to obtain the most benefit (Savari et al., 2023). When making decisions, it is important to consider bounded rationality as a limiting factor (Botzen et al., 2025; Puranam et al., 2015). Classical economics asserts that farmers have all the information they need and make choices that maximize their utility (Carter, 2016). However, according to bounded rationality, farmers often do not have all the information they need. They do not have enough time or are unable to analyze (Musshoff & Hirschauer, 2011; Xi & Zhang, 2020). For instance, a farmer might stick with traditional farming methods because they do not have access to new information or training on better methods, even if those methods could bring them more money. Additionally, a farmer choosing between crop varieties may analyze inputs, market prices, and expected yields before deciding (Lehmann et al., 2013). This approach, however, assumes that farmers have full access to information, perfect foresight, and unlimited cognitive capacity—assumptions that are rarely met in real-life farming situations.

Tian et al. (2023) indicate that social influence is very important in how farmers make decisions. In many rural areas, peers, family members, and community leaders often have a say in what crops to grow, whether to use new technologies, or whether to join a cooperative (Asprooth et al., 2023). Farmers may choose a method because it is good for business, fits with community practices, or is used by respected neighbors. This evidence shows that social pressures and expectations are a part of what it means to act rationally (Ramoglou et al., 2025).

Lastly, farming behavior is greatly influenced by non-economic factors such as gender roles and tradition (Bhujel et al., 2024). In most traditional societies, gender determines who can obtain land, credit, and extension services. This scenario often puts women at a disadvantage (Andrews et al., 2025). Local customs also decide what kinds of crops are grown or how they are grown, even if other methods might be more profitable (Noort et al., 2022). These factors show that utility maximization can influence behavior to some extent, but social structures and cultural values have a much bigger effect on decisions (Gavrilets et al., 2024). Additionally, these entrenched social norms can hinder innovation and limit the adoption of more efficient agricultural practices (Saberi et al., 2018). As a result, many communities may miss opportunities for growth and sustainability in their farming operations.

Aversion and the Role of Irrigation

According to UMT, individuals who are risk-averse generally make choices that lessen their exposure to uncertainty. Ghanaian farmers in regions susceptible to drought face considerable losses from unpredictable rainfall. Studies have indicated that irrigation could alleviate the risks linked to unreliable rainfall. Irrigation systems that supply more dependable water can lower the likelihood of crop failure, enable multiple cropping seasons, and enhance the expected utility (Koundouri et al., 2006). In this scenario, farmers might opt to invest in irrigation systems, such as drip or sprinklers, to guarantee a consistent water supply. Aside from ensuring a consistent water supply, irrigation can reduce water wastage and improve farmers' resilience to unpredictable weather patterns. Farmers can protect their crops from drought effects. Therefore, farmers' adoption of irrigation systems would not only mitigate the impact of drought on their crops but also increase their yield and income and improve livelihoods.

Irrigation systems entail both initial investment and ongoing expenses. The cost associated with establishing irrigation systems covers infrastructure, equipment, maintenance, and others (Ara et al., 2021; Ward, 2010). These investment costs are often significantly high for Ghanaian farmers in South Tongu, making them risk-averse and reliant on rainfed production. However, based on UMT, farmers will only commit to irrigation if the anticipated benefits surpass the costs involved. For instance, if farmers can observe improved productivity, increased earnings from increased yields, and the capacity to cultivate crops during off-seasons, their utility would be elevated (Chandio et al., 2020).

Nevertheless, financial limitations, access to credit, and government support can impact a farmer's capability and decision to invest in irrigation systems (Bjornlund et al., 2017). Some theoretical studies demonstrated that the availability of funding options impacted farmers' decisions to adopt irrigation. In Ghana, many farmers have encountered financial constraints that hinder their ability to cover the initial costs of irrigation systems (Amoah et al., 2018). UMT confirms that without credit or financial support for farmers, the costs associated with irrigation systems may surpass the anticipated advantages. Some past studies found that when farmers obtained low-interest loans or government grants, their expected utility from investing in irrigation systems grew (Shah et al., 2020). However, in the absence of such support systems, farmers, particularly in South Tongu, were reluctant to invest in irrigation infrastructure, fearing potential losses from unforeseen events, such as the reclamation of farmlands by landowners. Additionally, farmers feared incurring debts under such a scenario, thereby increasing their risk aversion. This illustrates the importance of credit support for farmers.

Irrigation has the potential to enhance income generation by allowing farmers to diversify their crops, boost yields, and reach higher-value markets (Chengappa, 2018). UMT explains that by optimizing income generation through expanded crop production and improved market access, farmers can enhance their overall well-being. Furthermore, as mentioned earlier, irrigation facilitates multiple cropping cycles in a single year. It also increases the quantity of produce sold, thus contributing to stable income (Fischer et al., 2022). Therefore, the capacity to maximize income and ensure a consistent revenue stream is an important consideration for farmers' choice to implement irrigation (Mango et al., 2018). Otherwise, these farmers become reluctant to invest in irrigation systems, as is the case with those in South Tongu.

The impact of government policies on the promotion of irrigation is yet another essential factor affecting utility maximization choices (Alcon et al., 2014). Policies that offer subsidies or credit support for irrigation infrastructure can alleviate the financial pressures on farmers and improve their capacity to invest in irrigation (Diao et al., 2010). Additionally, government initiatives that aim to enhance water availability for irrigation and provide training in water management can also add to higher utility, making irrigation more efficient and accessible to smallholder farmers.

Despite the benefits of irrigation, Ghana faces several obstacles in optimizing its utility through irrigation systems. These include high initial, operation, and maintenance costs, infrastructure limitations, and knowledge gaps (Baldwin & Stwalley, 2022). Farmers may avoid investing in irrigation if they perceive the costs to outweigh the benefits, especially when financial support is lacking, which highlights their risk aversion. Additionally, the scarcity of water sources and irrigation infrastructure in rural areas also limits the efficiency of irrigation systems (Osei, 2015). Over-irrigation or poor water management can cause soil erosion and deplete water sources, jeopardizing the long-term viability of irrigation practices. Therefore, enhancing utility through irrigation requires a comprehensive assessment of sustainable techniques (Koundouri et al., 2006).

Many farmers lack the technical expertise required for the effective implementation and maintenance of irrigation systems (McGinnis & Ostrom, 2014). Insufficient training and extension services can lead to ineffective use of irrigation technology, thereby limiting the potential utility benefits derived from such systems (Amoah et al., 2018). This lack of expertise can result in poor water management, inefficient use of resources, and reduced crop yields, highlighting the need for government and stakeholders to invest in training programs and extension services for farmers.

In South Tongu, there are not many subsidies or training programs for farmers, which might contribute to farmers' productivity and resilience. Right now, getting government subsidies for products such as fertilizers, better seeds, or irrigation equipment is not always easy and is often limited by paperwork and a lack of outreach. In the same way, some NGOs and agricultural extension services teach farmers about new farming methods and climate-smart practices. However, many smallholder farmers are still not receiving the help they need. A viable and doable plan would be to increase targeted subsidies along with practical, locally tailored training programs. The proposal would work best if it were done through existing local structures and cooperatives to make sure everyone has fair access and the programs last.

Contextualizing Utility Maximization and Melioration for Farmers

With regard to utility maximization, a farmer aims to plan long-term goals, such as selecting crops that will yield the highest return over multiple seasons (Robert et al., 2016). Such an endeavor would involve balancing immediate and future benefits. For example, they might invest in soil improvement or agroforestry that pays off in the long term (Herrick, 2019).

Melioration generally refers to the tendency to pursue immediate smaller rewards over long-term larger ones. Regarding melioration in agriculture, a farmer may focus on short-term cash needs by choosing to sell crops immediately (Mukhtorov et al., 2023), even though storing them for a later sale might yield higher profits (Sommer et al., 2013). This immediate decision-making, focusing on short-term rewards (like cash flow), is an example of melioration, where the farmer does not fully optimize long-term benefits (Adolph et al., 2021).

In economics, the consumer maximization problem involves optimizing utility subject to budget constraints (Lahiri, 2020). According to Tesfaye et al. (2021), a similar equation can be framed to understand the allocation of limited resources (time, labor, and capital) between farmers' competing needs or objectives. Farmers often face decisions involving the allocation of scarce resources such as land, labor, and capital (Tesfaye et al., 2021). These decisions might revolve around choosing crops, fertilizer use, and investment in new technologies, in this case, irrigation systems (Ara et al., 2021).

In applying utility maximization, farmers ideally aim to maximize their utility (e.g., overall crop yield, profit, or sustainability) over the long term (Umar, 2014). This could involve decisions such as investing in more sustainable farming practices, even though the benefits (such as improved soil fertility or higher yields in the future) might not be immediately visible. Therefore, utility maximization for farmers would focus on balancing immediate needs with long-term agricultural success and sustainability (Singh et al., 2016).

In terms of melioration, Sims et al. (2013) showed that farmers might often focus on immediate rewards rather than long-term planning. For instance, farmers might sell a crop quickly at a low price because they need immediate cash instead of storing it for a later period when prices could be higher. This reflects short-term decision-making that optimizes immediate benefits rather than considering the long-term benefits (Sims et al., 2013). In this case, the behavior aligns more with melioration, where farmers constantly seek short-term solutions without fully considering how long-term utility could be affected. The general form of the utility maximization equation is expressed in equation (1) below as:

$$Utility\ maximization = U(x_{,}x_2,\ldots,x_n) \quad (1)$$

Where:

U = the utility function, representing the well-being or satisfaction of a farmer.

$x_{1,}\, x_2,\ldots,\, x_n$ = the quantities of various goods or services consumed or produced by a farmer (crops, livestock, labor, fertilizer and seeds inputs, or investments in farm technology)

A smallholder farmer typically maximizes utility subject to constraints as expressed below:

$$Utility\ maximization = p_1 x_1 + p_2 x_2 + \ldots\ldots. + p_n x_n \leq I \quad (2)$$

Where:

$p_{1,}\, p_{2,} \ldots\ldots\ldots.p_n =$ the cost or price of the goods or services choice (e.g., cost of seeds, crops, fertilizers, tools),

$x_{1,}\, x_2,\ldots,\, x_n$ = the quantity of various goods or services

I = the income or total available resources, which may include earnings from farming, remittances or available budget.

In Ghana, smallholder farmers are often involved in subsistence farming with crops such as maize, cassava, and yam (Wahab et al., 2022). They also manage livestock. The utility maximization problem for these farmers may be expressed as below:

Utility maximization problem, U = f(crops, livestock, leisure, inputs, etc.) (3)

We adopted this model because it can guide farmers in maximizing their utility based on the available resources. The model made it clear how decisions about resource allocation and the selection of crops, inputs, and technology might interact (Janssen & Ittersum, 2007; Robert et al., 2016). Also, farmers can make informed decisions that will lead to greater efficiency and profitability in their operations (Tey & Brindal, 2015). To note here, it takes into account various factors such as market conditions, climate variability, and production costs to help farmers optimize their decision-making process (Robert et al., 2016). Therefore, adopting this model has the potential to revolutionize the way farmers approach their farming practices and improve productivity in the South Tongu district.

METHODOLOGY

Study Location

South Tongu district in the Volta Region of Ghana, where this study is situated, lies between latitudes 6°10' and 5°45' N and longitudes 30°30' and 0°45' E, covering a total land area of 665 km² and 75 meters above sea level (Ghana Statistical Service, 2021a; South Tongu District Assembly, 2021). It had a population of 113,114, of which 60,626 were females in 2021 (Ghana Statistical Service, 2021a; South Tongu District Assembly, 2021). At the time, the population had shown a general growing trend with an average household size of four persons. About 91% of the district population was engaged in agriculture, of whom 69% lived in rural areas (Agbi et al., 2018; Ghana Statistical Service, 2021b; Koku and Gustafsson, 2003; South Tongu District Assembly, 2021).

According to Koku and Gustafsson (2003), agriculture is the main source of livelihood for the people of South Tongu, and the area is dominated by small-scale rice and vegetable production with heavy reliance on rainfall. Moreover, farmers do not have adequate access to irrigation infrastructure, including canals, waterways, drainage, and reservoirs. Their farms suffer from low yields and seasonal flood damage as a result (File et al., 2023; GIZ, 2012; Nyantakyi-Frimpong et al., 2023).

The district is in the coastal savannah vegetation zone with swampy areas that are suitable for farming (Ghana Statistical Service, 2014; Koku, 2001; Peters & Kusimi, 2023), including heavy clayey loam soils with adequate particle-size distribution (Allotey et al., 2008). The grounds respond well to water content changes as clayey soils effectively retain nutrients, preventing leaching. Moreover, clays react well with hydrogen and aluminum ions and buffer the soil against extreme pH changes (Gazey & Davies, 2009; Newman, 1984). However, despite these advantages, the heavy clayey loam soils can also present challenges for farming, as their dense structure may lead to poor drainage and waterlogging during periods of heavy rainfall. Additionally, if not properly managed, the nutrient retention capability of clayey soils can lead to an accumulation of toxic elements.

The existing climate is characterized by southwest monsoon winds twice annually (Ghana Statistical Service, 2021b; South Tongu District Assembly, 2021). Rice is cultivated twice annually in most parts of the district due largely to rainfall availability. The major rainy season begins in late March or early April and continues through July. From May to June, 195 mm of rain falls on a daily average. The average daily rainfall during October through November is 73 mm. August is the driest month, with a temperature ranging from 22.6°C to 33°C, with a mean annual temperature of 27°C and an average humidity of 80% (Ghana Statistical Service, 2014; South Tongu District Assembly, 2021). Smallholder farmers start planting rice in late April and early May. In mid-August, they start harvesting. The second season often begins with farmers planting rice in early September. Then they harvest from late November to early December.

The cycles of vegetable crop cultivation are also influenced by the seasons. Farmers focus on cultivating early vegetables such as tomatoes, carrots, and cabbage, which benefit from the relatively drier conditions and are harvested in January and February. Farmers, at the onset of the major rainy season (April to June), cultivate leafy greens such as spinach, amaranth, and cocoyam leaves (locally known as kontomire). These vegetables thrive in the wetter conditions. At the peak of the major rainy season (July to September), farmers harvest various vegetables, including okra and eggplant. In transitioning to the dry season (October to December), farmers harvest root crops such as cassava and sweet potatoes. During this time, farmers also engage in post-harvest management practices to preserve produce and reduce losses.

In the Hikpo community within the South Tongu District, farmers have benefited from government interventions aimed at enhancing vegetable production and reducing post-harvest losses. The Ghana Peri-urban Vegetable Value Chain Project (GPVVCP) provided training in areas such as soil and nutrient management, agrochemical safety, and post-harvest handling. Moreover, farmers received support through the Ghana Green Label Certification Scheme, enabling them to access high-value markets and establish business relationships with exporters. These initiatives have equipped Hikpo farmers with the knowledge and resources to optimize their farming practices throughout the year, aligning their activities with seasonal variations to ensure a steady supply of vegetables to both local and external markets. However, irrigation access support is limited.

Rice, maize, and cassava are food security crops that are cultivated in the district. Rice is partly grown under irrigation. An average of 13.75 mt/ha of commercial rice is cultivated per annum on about 3,500 hectares of land at Kpenu and Fievie by Brazilian Agro and GADCO, respectively. Brazilian Agro and GADCO are the two largest commercial rice farms in the district under irrigation. The average landholdings of smallholder farmers are 0.6 ha, from which they produced 2.7 mt/ha of paddy rice in 2011 under rainfed conditions. Rice varieties primarily cultivated in the district include Jasmine 85, AGRA, Togo Marshal, Brown rice, and Sikamo. Pepper or chili dominates as the main cash crop among other vegetables grown by farmers in the district. The district department of agriculture often provides training and extension services to chili farmers for the export market (Asravor, 2016; Ghana Statistical Service, 2014; South Tongu District Assembly, 1996).

The South Tongu district in Ghana has abundant water resources that could support agriculture, but they have not been efficiently utilized for irrigation farming. The Water Resources Commission (WRC) Act, established in 1996, regulates and manages freshwater resources in the country. It grants water-use rights to farmers in the district and Ghana as a whole, and all projects and sub-activities must conform to the commission’s requirements. However, the lack of enforcement of laws governing farmers’ access to and use of water negatively impacts the use of surface water for agricultural purposes. Access to water depends on farmers’ accessibility, proximity, and availability of irrigation equipment and technology. Residential and recreational facilities, business structures, farmlands, and non-farmlands often obstruct canal routes for irrigation water access, making it difficult for smallholder farmers to draw water to their farms.

The Volta River runs through South Tongu District. Other streams include Alabo, Aklakpa, Kolo, Gblor, Bla, Anyorgborti, and Nyifla, along with tributaries of the Volta River. Many of these streams are seasonal and often disappear in the dry season. In the rainy season, they sometimes overflow their banks and inundate farms and roads. Farmers who are close to and have access to the Volta River and Avu Lagoon, among others, irrigate their rice paddies and vegetable farms. Stormwater from the River Tordzi flows into Avu Lagoon and occasionally floods its banks and most residential areas during the rainy seasons. Often in June and July, some farmers rely on these overflows to irrigate farms. Water levels recede in August. In October, levels rise again and eventually recede in December. Farming communities lack irrigation canals and rely on field bunding to save water for a short period. Some farmers near Avu Lagoon use sprinklers to irrigate (Koku and Gustafsson, 2003).

South Tongu, despite its potential for agricultural irrigation development, faces challenges from climate change. The Ghana Irrigation Development Authority (GIDA), an agency of the Ministry of Food and Agriculture, is tasked with developing irrigation plans, managing land and water resources, and collaborating with other agencies. Recent projects include the Ghana Wetland Management project, which aimed to enhance productivity and revitalize the local economy by providing irrigation water. The District Assembly under Village Infrastructure Projects (VIPs) has also introduced catchment planning and small-scale irrigation in some local farming communities. However, land-use-related issues remain significant constraints. The government's past plan to enforce small-scale irrigation development through external donors was positive, but it focused more on large-scale gravity-based surface irrigation, neglecting the increasing number of small-scale irrigators. These gap years without government support for irrigation among smallholders led to low irrigation availability.

An institutional approach to irrigation development emphasized farmers' roles and shared duties, but these conditions led to reduced public spending and increased burden on farmers without clear recognition of their rights and authority over decision-making. Many irrigation facilities were abandoned and eventually collapsed. Policies such as the Ghana Shared Growth and Development Agenda (GSGDA I and II), Food and Agricultural Sector Development Policy (FASDEP I and II), and Medium-Term Agricultural Sector Investment Plan (METASIP I and II) were introduced to strengthen irrigation development, but they failed to provide actual directions for developing and maintaining small-scale irrigation among farmers.

Data Collection and Analysis

In March 2023, we conducted a preliminary household survey in the field at Agbakope and Dorkploame. The survey involved interviewing farmers and some extension officers. In this study, we collected valuable information on farmers' needs for irrigated crop production. We carefully designed and prepared a questionnaire and uploaded it in the digital data collection tool called KoboToolbox. The tool simplified the data collection process and eventually storage and retrieval. All surveys were conducted with informed consent forms, and respondents were assured of anonymity and confidentiality. With the cooperation of trained enumerators, we then randomly distributed the questionnaire to 120 household farmers in the purposively selected communities from June to July 2023. The chosen communities were Tordzinu, Dorkploame, Gbenorkope, and Agbakope. The study communities were chosen on purpose due to the limited development of irrigation infrastructure among smallholder farmers. A focus group interview was conducted with the regional and district agriculture directorates, as well as community leaders/opinion leaders in the district. They had relevant knowledge about the needs of farmers in the area. The purpose of the interview was to inquire about smallholder farmers' needs for irrigated crop production. These interviews were used to validate our findings from the questionnaire.

The questionnaire was divided into two main sections. The first section focused on the socio-demographic factors of smallholder farmers, including gender, age, education, farm size, farm income, and residence years. The second section examined farmers' needs for irrigated crop production in the study area. The survey consists of Likert-scale questions that provided a range of response alternatives to understand the extent of agreement among respondents. For data analysis, we utilized SPSS software version 27 and Excel to generate tables and figures. For our presentation of the results, we utilized descriptive statistics, specifically frequencies and percentages.

Past theoretical studies have employed the utility maximization and risk aversion theories to explain individuals' or groups' decision-making and choices regarding medical decision-making, energy renewal, and distribution systems, among others (Dieudonné et al., 2024; Kheybari et al., 2024; Mulligan et al., 2024; Sinha, 2020). Similarly, our study also further applies utility maximization and risk aversion theories to explain how farmers navigate the trade-offs between irrigated and rain-fed production systems in the study area. The theories explain how farmers seek to maximize their benefits while minimizing uncertainty and potential losses, especially in the face of unpredictable rainfall, water availability, and financial constraints. For instance, in irrigated systems, risk-averse farmers may opt for reliable water sources and efficient irrigation technologies to ensure stable yields, even if the initial investment is high. Conversely, in rain-fed systems, where water supply depends on rainfall patterns, farmers may adopt drought-resistant crops, soil moisture conservation techniques, or crop diversification to mitigate risks. Utility maximization theory can be linked to farmers' choices for agricultural practices that provide the greatest benefits based on their needs for irrigated crop production.

RESULTS AND DISCUSSION

Socio-Demographic Characteristics of the Respondents

Table 1 shows the socio-demographic characteristics of the respondents (smallholder rice and vegetable farmers). For gender, our results have shown that males (62%) were represented slightly more. However, female farmers were not entirely engaged in farming because of other domestic duties such as childcare, cooking, and water collection. The 2021 population and housing census data revealed that females constituted 54% of the surveyed area, while the average household size was four persons (Ghana Statistical Service, 2021). According to the Ghana Statistical Service (2021), the regional and national census records revealed a trend that was comparable in terms of gender distribution and average household size.

The age distribution revealed that 48% of the responding farmers belonged to the 50-59 and 60-69 age groups, with a mean age of 60 years. This finding demonstrates the farming communities' aging pattern. It means that as farmers age, their physical capacity to perform labor-intensive tasks, such as manual watering and soil moisture management, declines. This result is consistent with a study by Liu et al. (2023) in China, which found that farm tasks such as snow removal from greenhouse roofs and draining fields are mainly heavy work for older farmers. In connection with risk aversion theory, older farmers might become more cautious and less willing to take on risky investments or adopt new technologies such as irrigation. Furthermore, crop failure may pose a financial risk for older farmers who rely on farming as their primary source of income. Therefore, efficient irrigation systems could help reduce physical strain and sustain productivity.

Regarding the educational background of the responding farmers, 60% had attained primary education. From a utility maximization perspective, this finding suggests that the farmers were literate and better equipped to access and understand information, enabling them to make informed decisions that could enhance productivity and satisfaction (utility). Farmers' literacy might reduce uncertainty and make them better evaluate risks, follow best practices, and adopt new technologies to minimize losses and align with risk-averse behavior. This result is consistent with studies by Choruma et al. (2024) in Sub-Saharan Africa and Shahzad et al. (2024) in Punjab, Pakistan.

In terms of farm size, 49% of farmers operated on less than 5 acres of land. This suggests that farmers may avoid taking financial risks associated with acquiring or managing larger farm sizes. Instead, they may prefer to manage smaller farms, reflecting risk-averse behavior. It could also mean that the farm size was too small for farmers to invest in irrigated crop production with a reasonable return on investment. Additionally, small farm sizes may limit the variety of crops a farmer is willing or able to grow. Moreover, farmers may be restricted to cultivating only rain-fed crops, which are more vulnerable to fluctuations in weather patterns and offer limited opportunities for crop diversification. Similar findings were reported by Urfels et al. (2023) in Eastern India, who found that small farm sizes constrain the potential for irrigation-led agricultural intensification to significantly increase incomes.

The results show that 58% of farmers reported earnings ranging from GH₵5,000 to GH₵7,000 (equivalent to $324.62 to $454.47) per season. Although this amount may seem relatively high, it is insufficient to cover the costs of irrigation system installation, labor, and farm inputs. Only 9% of the responding farmers reported earning more than GH₵7,000 (over $454.47) per season, which is still inadequate for investing in irrigation. This data indicates that a minority of farmers may be employing more efficient or profitable farming practices, demonstrating the importance of providing credit support, financial planning assistance, and access to irrigation to reduce production costs and enhance profitability. Bessah et al. (2022) found that limited access to financial capital constrained farmers from adopting irrigation practices. However, in contrast to our findings, some previous studies have estimated the cost of establishing new irrigation facilities to range from $5,000 to $20,000 per hectare (Atuobi-Yeboah et al., 2020; Baldwin & Stwalley, 2022; Namara et al., 2014; Svendsen et al., 2011). These significant costs might deter farmers from investing in irrigation, especially in regions where financial resources are already limited.

Our survey results show that 53% of the responding farmers had lived in the study area for more than 35 years. This suggests that they may possess substantial knowledge about the local environment, customs, society, and irrigation needs. Long-term residency implies that these farmers have likely witnessed changes in the community over time and have developed a profound understanding of both the challenges and opportunities present. Such knowledge could be invaluable for policymakers and government agencies in designing and tailoring interventions to meet the specific needs of farming communities. Moreover, this evidence suggests that any initiatives aimed at improving farmers' irrigated crop production might succeed. This result aligns with the findings of Yan et al. (2023), who reported that long-term residents often have extensive knowledge of local soil conditions and crop management practices.

Table 1: Socio-Demographic Characteristics of Respondents

Socio-demography	Category	Frequency	Percentage (%)
Gender	Male	74	62
	Female	46	38
	18-29	4	3
Age (Years)	30-39	13	11
	40-49	45	38
	50-59	34	28
	60-69	24	20
	No formal	17	14
Education level	Primary/Basic	72	60
	Secondary	29	24
	Tertiary	2	2
Farm size (acreage)	< 5 Acres	59	49
	5-9	23	19
	10-14	13	11
	15-19	9	8
	20-24	5	4
	More than 24	11	9
Farm income (GH₵)	< 3000	6	5
	3000-3999	15	13
	4000-4999	18	15
	5000-5999	29	24
	6000-7000	41	34
	More than 7000	11	9
Years lived	< 5 years	10	8
in the district	5-14	18	11
	15-24	22	13
	25-34	18	15
	35-44	17	23
	Above 44	35	30

Source: Field Survey, (2023)

Distance of Farms from Available Irrigation Water Sources (Meters)

The study surveyed farmers in various communities about their water sources, including the Lower Volta River, Tordzi River, streams, and the spillage from Avu Lagoon (Figure 2). The result shows that respondents (98%) did not consider streams as their water source. However, 75% of farmers were far from the spillage of Avu Lagoon, and most farms were situated upstream, making access difficult. About 67% of farmers were not close enough to the Lower Volta River, citing recreational and residential facilities along its banks as barriers. Similarly, 57% of farmers were not close to the Tordzi River. Therefore, limited access to irrigation water compels farmers to rely primarily on rainfall.

To understand the extent of water sources not used for irrigation, respondents were asked to indicate the distance from their farms to water sources. The results show that 98% of farmers were located more than 600 meters from streams, 75% were 500-599 meters from the spillage from Avu Lagoon, 67% were 400-499 meters from the Lower Volta River, and 57% were between 100 and 200 meters from the Tordzi River. This implies that the cost of connecting irrigation canals to farms may be high for farmers. Potential canal routes were obstructed by residential structures and neighboring farms, making it difficult to draw water through adjacent properties. Only a few farms were located along the riverbanks, and there were no canals to channel water to other farms.

A further survey revealed that 92% of farmers preferred to have their irrigation water intake within 60 meters of their farms. Such proximity can reduce infrastructure development costs, minimize water loss and the risk of infrastructure failure, and enhance productivity. However, even farms located near water sources still rely on rainfall—possibly due to constraints such as inadequate start-up capital and limited skills in irrigation installation. The survey also indicated that with shorter distances to water sources, farmers may lower labor and input costs, contributing to greater satisfaction and utility.

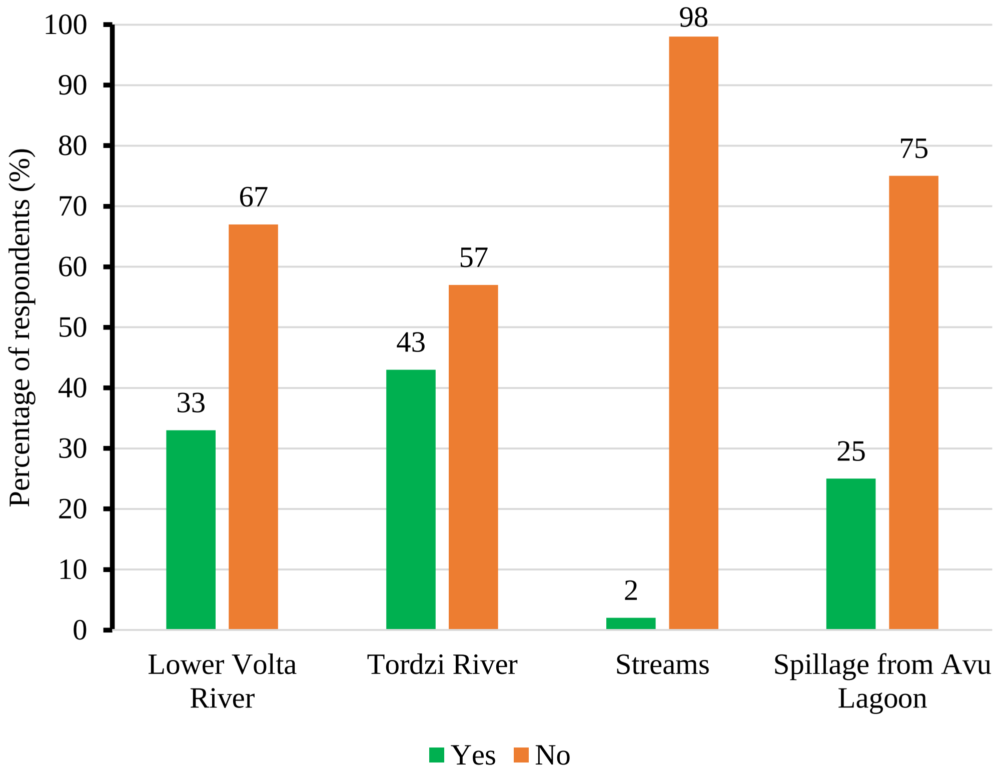

Figure 2: Proximity of Water Sources to Smallholder Farmers

Source: Field Survey, (2023)

Smallholder Farmers' Irrigation Practices and Benefits

The survey revealed that 44% of farmers relied on traditional flood recession irrigation systems, which were less costly and cheaper than furrow, drip, and sprinkler systems. Farmers observed flood levels during crop cultivation. But heavy rains sometimes caused overflooding, causing crop damage. Flood recession is common in floodplains, lake margins, and wetlands, as reported by Everard (2018) and Sall et al. (2020).

The survey shows that 27% of respondents used furrow irrigation systems for flood recession, while 15% used sprinkler irrigation. It means these farmers understood irrigation benefits and used sprinkler systems to enhance their existing system. About 9% used furrow irrigation, and only 5% used drip irrigation. However, the cost of drip irrigation was high for farmers, hence their risk-aversion behavior. Only those farmers with financial capacity and education practiced drip irrigation. Overall, farmers' knowledge and willingness to adopt new irrigation methods might contribute to their satisfaction.

Regarding the benefits of irrigation to smallholder farmers, we asked the respondents multiple-choice questions to understand their agreement levels on the benefits of irrigation with a yes or no response (Figure 3). We offered the following statements: it saves time, it is cost-effective, it saves labor costs, and it secures a higher yield than rainfed. The result showed that the respondents (83%) agreed that irrigation secures a higher yield than rainfed. In connection with the results on farmers' literacy, it means that the responding farmers understood the merits of irrigation farming, indicating that they were well-informed about its benefits. Tack et al. (2017) found a more positive impact of irrigation on increased yield than rain-fed.

In terms of labor cost, the responding farmers (62%) agreed that irrigation saves labor costs. It means that automated irrigation systems might reduce farmers' need to secure manual watering services at a fee. Moreover, farmers might allocate their labor costs to other essential farm activities to save money and increase efficiency and productivity. Farmers might use their limited resources more efficiently to increase net benefit or satisfaction, aligning with utility maximization theory.

Regarding timing, about 54% of the respondents agreed that irrigation saves time. It means that irrigation systems free up time for farmers to focus on other aspects of their farm operations. The finding highlights the importance of incorporating modern technology into agriculture to maximize productivity and income. This result further reflects risk-averse behavior among farmers, as saving time with irrigation reduces uncertainty and potential losses related to delayed farm activities like planting and harvesting.

About half of the respondents (52) agreed that irrigation is cost-effective. It means that adopting irrigation systems can reduce water waste, especially in regions where water scarcity is a pressing issue. These farmers might prefer options that provide greater benefits at lower costs, which aligns with utility maximization.

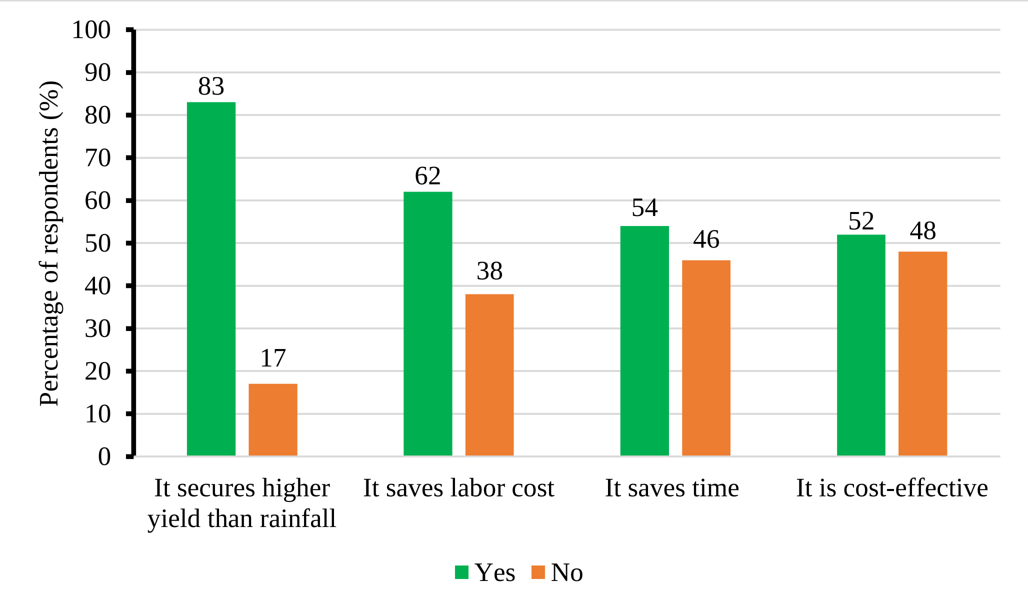

Figure 3: Benefits of Irrigation to Smallholder Farmers

Source: Field Survey, (2023)

Smallholder Farmers' Needs for Future Irrigation Development

As illustrated in Figure 4, the survey tried to understand smallholder farmers' needs for future irrigation development. We provided a yes or no response to the following questions: Do you need credit support? Do you need waterways? Do you need a canal? Do you need ready markets? Do you need technical support? Do you need irrigation equipment support, and do you need extension support from the government?

Respondents emphasized the importance of credit support for farm growth, expansion, and investment in new technologies, indicating the role of credit access in farm businesses of all sizes. On the other hand, farmers may struggle to keep up with the demands of a competitive market and may be limited in their ability to innovate and adapt to changing conditions without credit access. It means that farmers might find it difficult to cover unexpected expenses or recover from setbacks such as natural disasters or crop failures. Farmers might be unable to diversify farm operations, which relates to the utility maximization theory, emphasizing the importance of credit support for farmers to thrive and remain competitive.

The result shows that the respondents (74%) proposed a need for canal development. It means that in connection with farmers' literacy, risk aversion, and utility maximization theories, farmers required canals to improve irrigation practices for increased yields. Canal expansion, a logical option, indicates a risk-averse mindset among farmers. Moreover, from the standpoint of utility maximization theory, farmers will strive to make decisions that can enhance their utility. This indicates that there must be support for canal development to mitigate the effects of irregular rainfall.

Respondents (74%) identified ready markets as a need for their produce, indicating that farmers are not only concerned with producing crops but also with ensuring demand for their produce. A ready market provides a sense of security, allowing farmers to focus on improving their yields and fostering long-term relationships with buyers. This aligns with the risk aversion theory, which suggests that individual farmers prefer outcomes with less risk and greater certainty. For risk-averse farmers, a ready market lowers income uncertainty and provides them confidence.

The result indicates that farmers (71%) required irrigation equipment support. It means that without government subsidies, farmers may struggle to maintain their crops and suffer financial losses. Moreover, if farmers cannot maintain their crops, they may abandon their fields, meaning they require irrigation equipment support. According to the utility maximization theory, farmers with limited resources might allocate them in ways that maximize satisfaction or welfare, consistent with the findings of Liu et al. (2024).

The survey result has shown that farmers (64%) needed technical support. It means that farmers may continue to struggle with inefficient water use, soil moisture imbalances, and lower crop yields without technical guidance. Moreover, efficient irrigation requires knowledge of water management, system selection, maintenance, and resource optimization. This conclusion underscores the need for extension services, training programs, and other support systems to build farmers' capacity in irrigation farming, consistent with the results of Knox et al. (2012).

The utility maximization theory suggests that individuals make choices to maximize their satisfaction based on income, information, and resource constraints. The result indicates that respondents (54%) needed extension support, suggesting that farmers may need additional assistance to understand and implement technical information on irrigation. It is crucial for extension services to be accessible and readily available to meet individual farmers' irrigated crop production needs by addressing information constraints and enabling them to make informed choices for enhanced utility.

Regarding waterways, about 53% expressed a need. It shows farmers' desire to reduce flood-related risks and crop failure. It means that waterways can prevent flood damage on farms. Waterways can efficiently channel flood and irrigation water, preventing waterlogging and soil erosion. According to risk aversion theory, farmers might prefer to minimize uncertainty and potential losses, highlighting the need for improved water infrastructure to support them.

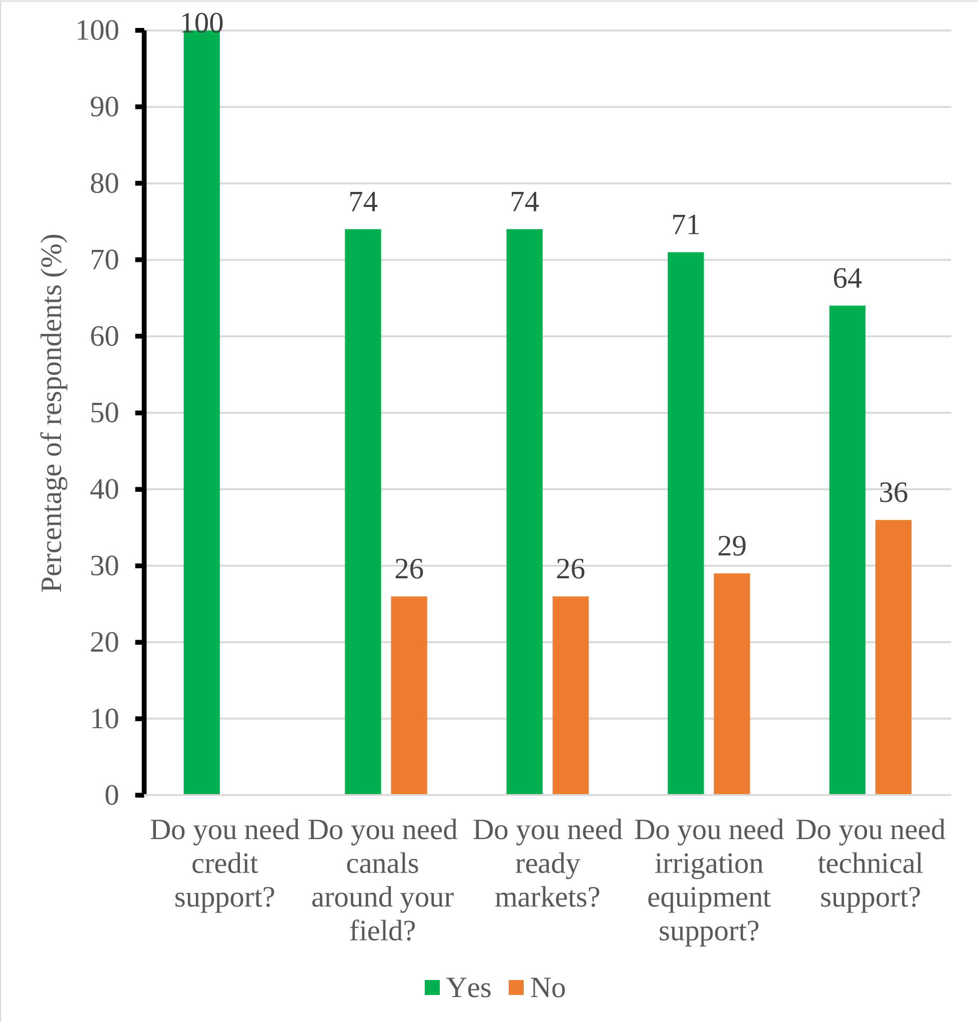

Figure 4: Smallholder Farmers' Irrigation Needs

Source: Field Survey, (2023)

Smallholder Farmers' Annual Rice Paddy Yield per Acre

Rice production is mainly rain-fed in the study area with little irrigation supplement. About 80 farmers mainly cultivated rice under rain-fed conditions. Our preliminary field survey and observation have shown that, in general, when rice paddy is milled, its volume and weight reduce to almost half of the initial harvested amount. Our survey, therefore, attempted to find out the average annual rice yields that farmers obtain under rain-fed conditions (Table 2). We asked the responding farmers to choose from the following ranges that we provided: (1) less than 20 bags; (2) 20-29 bags; (3) 30-39 bags; (4) 40-49 bags; (5) above 49 bags. The result shows that respondents (59%) obtained a maximum yield range of 20-29 bags on average per annum per acre under rain-fed conditions. Others (18%) obtained a maximum range of 30-39 bags. About 11% noticed a maximum yield of 40-49 bags. Only 6% harvested a little above 49 bags. Another 6% had a maximum of less than 20 bags.

The result further shows that 59% obtained 15-24 bags. Those who had 25-34 bags represented 23%. About 13% had 35-44 bags at a minimum. Only 5% had fewer than 15 bags. It means that with secured access to irrigation, farmers' rice yield can be improved from their current levels, consistent with Ringler et al. (2020), who found that irrigation supports higher crop yields by 30-60% more than rainfed systems.

Comparatively, responding farmers (59%) obtained a yield of 2.45 mt/ha under rain-fed conditions. This yield is lower than the average district potential yield of 3.5 mt/ha of paddy rice. It is also lower than the national average yield of 2.96 mt/ha with no irrigation access (MoFA, 2021). On the contrary, Amanor-Boadu (2012) found that the average yield in coastal, Guinea, and Sahel savanna areas of Ghana was above 2.96 mt/ha under rain-fed conditions. It shows that our average yield is still significantly lower than the average yield of 5.48 mt/ha obtained in the Greater Accra region, where technology and other improved rice intensification systems were used. Similarly, in Senegal, Benin, and Mali, the average yield was even higher in 2010, with 4.10 mt/ha, 4.07 mt/ha, and 3.36 mt/ha, respectively, with irrigation access (Amanor-Boadu, 2012). Also, because of the deplorable or poor state of irrigation and irrigable lands and poor irrigation infrastructure, rice is cultivated once per annum in South Tongu.

Table 2: Smallholder Farmers' Annual Paddy Rice Yield

Maximum yield (bags)			**Minimum yield (bags)**		
Categories	**Frequency**	**Percentage (%)**	**Categories**	**Frequency**	**Percentage (%)**
< 20 bags	5	6	< 15 bags	4	5
20-29	47	59	15-24	47	59
30-39	14	18	25-34	18	23
40-49	9	11	35-44	11	13
Above 49	5	6	-	-	-
Total	**80**	**100**		**80**	**100**

n = 80 respondents

*1 bag is equivalent to 100 kilograms of paddy rice. One metric ton is equal to 1000 kilograms. The average rice yield for most respondents (59%) with 20-29 bags of 100 kg each is 2.45 metric tons.

CONCLUSION AND RECOMMENDATIONS

This paper examined smallholder farmers' needs for irrigated crop production in the South Tongu district of Ghana. The paper identified several interconnected factors to explain why smallholder farmers were unable to irrigate their farms despite the high irrigation potential of the various communities. The risk aversion and utility maximization theories were further employed to explain farmers' needs for irrigated crop production. The socio-demographic analysis showed that respondents' gender, age, education, farm size, income, and years of residency were significantly related to their inability to employ irrigation on their farms. Female farmers were not entirely engaged in farming due to domestic duties. Responding farmers were literate and interested in irrigating their farms. Some agreed that irrigation secures a higher yield than rainfed, while others acknowledged that irrigation saves labor costs and time and is cost-effective. However, the aging trend and low farm income of these farmers discouraged them from investing in irrigation farming. The farmers were unable to develop smaller farm sizes due to unrealistic returns resulting from their risk-averse behavior.

The South Tongu district has high agricultural potential due to its abundant water availability and arable lands. However, farmers in the selected communities are not close enough to natural and irrigation water sources, limiting their ability to produce inland valley rice and vegetables. Factors such as insufficient credit, less rainfall, high temperatures, labor shortages, and inadequate technical support for efficient water application methods contributed to farmers' constraints for irrigated crop production. Inadequate irrigation equipment support, unavailability of markets, and perceived high input costs also contributed to farmers' failure to adopt irrigation in the district. Lack of canal routes and waterways around farms also hindered flood damage mitigation. Farmers who are not near water sources face land encroachment and water rights conflicts, and potential canal routes are obstructed by residential facilities and neighboring farms. Traditional flood recession irrigation systems were favored over furrow, drip, and sprinkler systems due to cost. Capacity building in water-efficient irrigation systems, such as drip irrigation, should be encouraged. Farmers obtained an average rice yield of 2.45 mt/ha, lower than the 5.48 mt/ha obtained in Greater Accra with irrigation access, indicating the need for irrigation adoption to increase yield.

To improve irrigation needs among smallholder farmers in the South Tongu district, it is recommended that they form groups or farmer-based organizations (FBOs) to seek assistance from benevolent organizations for irrigation equipment support and infrastructural development. Public-private partnerships are needed to construct weirs and canals and improve existing irrigation schemes. A bottom-up approach should be adopted, involving indigenous people in water and land use management. The government should intensify support and supervision and increase the number of extension officers. The district assembly should incorporate irrigation infrastructural development in its annual work plan, collaborate with government, farmers, and stakeholders to construct reservoirs, and distribute weirs. The assembly should provide selected irrigation technologies based on successful small-scale irrigation development experiences. Building farmers' capacity and equipping them with new skills and knowledge is crucial for enhancing food security and improving livelihoods.

Authors' Contributions

This article involves contributions from all three authors. The lead author, T. M. K., developed the methodology and wrote the article. A. E. J. contributed to the article editing, data curation, and review. N. J. A. contributed to the theoretical framework and proofreading. All authors endorsed the final version of the manuscript.

Acknowledgement

We express our appreciation to the Directorate of Agriculture in the South Tongu District of Ghana for their cooperation in collecting the data for this article. We extend our gratitude to the concerned farmers who participated in the questionnaire interview.

REFERENCES

Abdallah, A. H., Ayamga, M., & Awuni, J. A. (2023). Large-scale land acquisition and household farm investment in northern Ghana. *Land*, *12*(4), 1–36. https://doi.org/10.3390/land12040737

Abegunde, V. O., Sibanda, M., & Obi, A. (2019). The dynamics of climate change adaptation in Sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers. *Climate*, *7*(11), 1–23. https://doi.org/10.3390/cli7110132

Acheampong, D., Balana, B. B., Nimoh, F., & Abaidoo, R. C. (2018). Assessing the effectiveness and impact of agricultural water management interventions: the case of small reservoirs in northern Ghana. *Agricultural Water Management*, *209*, 163–170. https://doi.org/10.1016/j.agwat.2018.07.009

Adolph, B., Allen, M., Beyuo, E., Banuoku, D., Barrett, S., Bourgou, T., Bwanausi, N., Dakyaga, F., Derbile, E. K., Gubbels, P., Hié, B., Kachamba, C., Naazie, G. K., Niber, E. B., Nyirengo, I., Tampulu, S. F., & Zongo, A. F. (2021). Supporting smallholders' decision making: Managing trade-offs and synergies for sustainable agricultural intensification. *International Journal of Agricultural Sustainability*, *19*(5–6), 456–473. https://doi.org/10.1080/14735903.2020.1786947

Agbi, F. A., Dai, B., & Asamoah, E. O. (2018). Assessing patients' choice of service quality in the healthcare sector in Ghana: A case study of Sogakope District Hospital and Comboni Hospital. *British Journal of Interdisciplinary Research*, *9*(1), 1–20. http://onlinejournal.org.uk/index.php/BJIR/index

Agodzo, S. K., Bessah, E., & Nyatuame, M. (2023). A review of the water resources of Ghana in a changing climate and anthropogenic stresses. *Frontiers in Water*, *4*, Article 973825. https://doi.org/10.3389/frwa.2022.973825

Ahmadi, A., Keshavarz, M., & Ejlali, F. (2025). Resilience to climate change in agricultural water-scarce areas: The major obstacles and adaptive strategies. *Water Resources Management*, *39*(3), 1195–1214. https://doi.org/10.1007/s11269-024-04019-z

Akrofi, N. A., Sarpong, D. B., Somuah, H. A. S., & Osei-Owusu, Y. (2019). Paying for privately installed irrigation services in Northern Ghana: The case of the smallholder Bhungroo Irrigation Technology. *Agricultural Water Management*, *216*, 284–293. https://doi.org/10.1016/j.agwat.2019.02.010

Alcon, F., Tapsuwan, S., Brouwer, R., & de Miguel, M. D. (2014). Adoption of irrigation water policies to guarantee water supply: A choice experiment. *Environmental Science & Policy*, *44*, 226–236. https://doi.org/10.1016/j.envsci.2014.08.012

Allotey, D. F. K., Asiamah, R. D., Dedzoe, C. D., & Nyamekye, A. L. (2008). Physico-chemical properties of three salt-affected soils in the lower Volta Basin and management strategies for their sustainable utilization. *West African Journal of Applied Ecology*, *12*(1), 1–14.

Amanor-Boadu, V. (2012). *Rice price trends in Ghana (2006–2011)* (METSS-Ghana Research and Issue Paper Series No. 02-2012, pp. 1–13). METSS-Ghana.

Amoah, P., Afrane, G., & Asante, F. (2018). The role of irrigation in the economic development of agriculture in Ghana. *Agricultural Economics and Research Review*, *31*(2), 243–258.

Andrews, N., Anku, J. H., & Akolgo-Azupogo, H. (2025). Gender, land grabbing and agrarian livelihoods: Contradictory gendered outcomes of land transactions in Ghana. *The Journal of Peasant Studies*, *advance online publication*, 1–24. https://doi.org/10.1080/03066150.2025.2451792

Angom, J., & Viswanathan, P. K. (2023). Irrigation technology interventions as potential options to improve water security in India and Africa: A comparative review. *Sustainability*, *15*(23), 16213. https://doi.org/10.3390/su152316213

Ankrah, D., Okyere, C., Mensah, J., & Okata, E. (2023). Effect of climate variability adaptation strategies on maize yield in the Cape Coast Municipality, Ghana. *Cogent Food & Agriculture*, *9*(1), 1–23. https://doi.org/10.1080/23311932.2023.2247166

Antwi-Agyei, P., Dougill, A. J., Stringer, L. C., & Codjoe, S. N. A. (2018). Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. *Climate Risk Management*, *19*, 83–93. https://doi.org/10.1016/j.crm.2017.11.003

Ara, I., Turner, L., Harrison, M. T., Monjardino, M., DeVoil, P., & Rodriguez, D. (2021). Application, adoption and opportunities for improving decision support systems in irrigated agriculture: A review. *Agricultural Water Management*, *257*, 107161. https://doi.org/10.1016/j.agwat.2021.107161

Asfaw Eshetu, A., & Mekonen, A. A. (2024). Determinants of small-scale irrigation adoption in drought-prone areas of northcentral Ethiopia in the context of climate change. *Frontiers in Climate*, *6*, Article 1410527. 1–16. https://doi.org/10.3389/fclim.2024.1410527

Asprooth, L., Norton, M., & Galt, R. (2023). Transforming the corn belt: A recipe for collaborative, farmer-driven research and diffusion of innovation. *Journal of Rural Studies*, *103*, 103133.

Asravor, J., Onumah, E. E., & Osei-Asare, Y. B. (2016). Efficiency of chili pepper production in the Volta Region of Ghana. *Journal of Agricultural Extension and Rural Development*, *8*(6), 99–110.

Atuobi-Yeboah, A., Aberman, N. L., & Ringler, C. (2020). *Smallholder irrigation technology diffusion in Ghana: Insights from stakeholder mapping*. International Food Policy Research Institute. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3729390

Azumah, S. B., Adzawla, W., Osman, A., & Anani, P. Y. (2020). Cost-benefit analysis of on-farm climate change adaptation strategies in Ghana. *Ghana Journal of Geography*, *12*(1), 29–46. https://doi.org/10.4314/gjg.v12i1.2

Baffour-Attah, F., Mensah, S. C., Kuutiero, R. P., Adu, E. O., Amo-Mesi, P., Aturu-Essel, K., Quarshie, J. L., Fayorsey, M., Asaah, E., & Essuah, G. (2025). Perceived costs and benefits of different climate change adaptation practices used by smallholder farmers for agricultural production in the Ahafo Ano South District, Ghana. *Regional Environmental Change*, *25*(1), 29. https://doi.org/10.1007/s10113-024-02351-z

Balana, B. B., & Akudugu, M. A. (2023). Economic analysis of public investment in alternative agricultural water management schemes: A case study from northern Ghana. *Water International*, *48*(1), 40–62. https://doi.org/10.1080/02508060.2022.2156224

Baldwin, G., & Stwalley, R. M. (2022). Opportunities for the scale-up of irrigation systems in Ghana, *West Africa. Sustainability*, *14*(14), 1–18. https://doi.org/10.3390/su14148716

Bazzana, D., Comincioli, N., El Khoury, C., Nardi, F., & Vergalli, S. (2023). WEF Nexus policy review of four Mediterranean countries. *Land*, *12*(2), 1–18. https://doi.org/10.3390/land12020473

Bedo, D., Mekuriaw, A., & Bantider, A. (2024). Adaptive responses and determinants of adaptation decisions to climate change: Evidence from rainfed-dependent farmers in the Central Rift Valley of Ethiopia. *Cogent Food & Agriculture*, *10*(1), 2430404. https://doi.org/10.1080/23311932.2024.2430404

Begho, T., & Balcombe, K. (2023). Attitudes to risk and uncertainty: New insights from an experiment using interval prospects. *SAGE Open*, *13*(3), 1–16. https://doi.org/10.1177/21582440231184845

Bessah, E., Donkor, E. A., Raji, A. O., Taiwo, O. J., Ololade, O. O., Strapasson, A., Amponsah, S. K., & Agodzo, S. K. (2022). Factors affecting farmers' decision to harvest rainwater for maize production in Ghana. *Frontiers in Water*, *4*, Article 966966. https://doi.org/10.3389/frwa.2022.966966

Bhujel, R. R., & Joshi, H. G. (2024). Unveiling sustainable agriculture dynamics: A socio-psychological exploration among smallholder farmers in Sikkim, India. *Cogent Social Sciences*, *10*(1), 2350118. https://doi.org/10.1080/23311886.2024.2350118

Bjornlund, H., van Rooyen, A., & Stirzaker, R. (2017). Profitability and productivity barriers and opportunities in small-scale irrigation schemes. *International Journal of Water Resources Development*, *33*(5), 690–704.

Botzen, W. J., Thepaut, L. D., & Banerjee, S. (2025). Kahneman's insights for climate risks: Lessons from bounded rationality, heuristics and biases. *Environmental and Resource Economics*, 1–26. https://doi.org/10.1007/s10640-025-00980-4

Bowan, P. A., Anzagira, L. F., Issahaku, Z., & Bang-Era, F. A. (2023). An evaluation of small-scale irrigation schemes infrastructure. *Journal of the Ghana Institution of Engineering*, *23*(3), 8–17. https://doi.org/10.56049/jghie.v23i3.74

Carter, M. R. (2016). What farmers want: The "gustibus multiplier" and other behavioral insights on agricultural development. *Agricultural Economics*, *47*(S1), 85–96. https://doi.org/10.1111/agec.12312

Chandio, A. A., Arshad, M., & Shah, M. H. (2020). Irrigation and its impact on agricultural productivity in developing countries: A case study of Pakistan. *Water Economics and Policy*, *6*(2), 1–15. https://doi.org/10.1142/S2382624X20500185

Chanza, N. (2018). Limits to climate change adaptation in Zimbabwe: Insights, experiences and lessons. In *Limits to climate change adaptation* (pp. 109–127). Springer. https://doi.org/10.1007/978-3-319-72653-5_7

Chengappa, P. G. (2018). Development of agriculture value chains as a strategy for enhancing farmers' income. *Agricultural Economics Research Review*, *31*(1), 1–12. https://doi.org/10.5958/0974-0279.2018.00001.0

Choruma, D. J., Dirwai, T. L., Mutenje, M., Mustafa, M., Chimonyo, V. G. P., Jacobs-Mata, I., & Mabhaudhi, T. (2024). Digitalisation in agriculture: A scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in Sub-Saharan Africa. *Journal of Agriculture and Food Research, 18*, 1–10. https://doi.org/10.1016/j.jafr.2024.101286

Danish, M. S. S., Senjyu, T., Sabory, N. R., Danish, S. M. S., Ludin, G. A., Noorzad, A. S., & Yona, A. (2017). Afghanistan's aspirations for energy independence: Water resources and hydropower energy. *Renewable Energy, 113*, 1276–1287. https://doi.org/10.1016/j.renene.2017.06.090

Datta, P., & Behera, B. (2024). Assessing farmers' maladaptation to climate change in a sub-Himalayan region of India. *Environment, Development and Sustainability, 26*(12), 30621–30638. https://doi.org/10.1007/s10668-023-03925-3

De Janvry, A., Sadoulet, E., & Zhu, N. (1997). The economics of smallholder irrigation in developing countries. *World Development, 25*(12), 2067–2081. https://doi.org/10.1016/S0305-750X(97)00073-1

Diallo, A., Donkor, E., & Owusu, V. (2020). Climate change adaptation strategies, productivity, and sustainable food security in southern Mali. *Climatic Change, 159*(3), 309–327. https://doi.org/10.1007/s10584-020-02684-8

Diao, X., Hazell, P. B., & Thurlow, J. (2010). The role of agriculture in African development. *World Development, 38*(10), 1405–1413. https://doi.org/10.1016/j.worlddev.2009.12.003

Dieudonné, D., Ewanga, D., & Ernst, D. (2024). Decision making and risk aversion under uncertainty in energy renewable and operational of flexibility of distribution system network. https://doi.org/10.46855/energy-proceedings-11183

Dinko, D. H., & Nyantakyi-Frimpong, H. (2023). Uneven geographies of the embodied effects of water insecurity among women irrigators in northern Ghana. *Annals of the American Association of Geographers, 113*(10), 2417–2434. https://doi.org/10.1080/24694452.2023.2231528

Dinye, R. D., & Ayitio, J. (2013). Irrigated agricultural production and poverty reduction in northern Ghana: A case study of the Tono Irrigation Scheme in the Kassena Nankana District. *International Journal of Water Resources and Environmental Engineering, 5*(2), 119–133. https://doi.org/10.5897/IJWREE12.129

Durga, N., Schmitter, P., Ringler, C., Mishra, S., Magombeyi, M. S., Ofosu, A., ... & Matambo, C. (2024). Barriers to the uptake of solar-powered irrigation by smallholder farmers in Sub-Saharan Africa: A review. *Energy Strategy Reviews, 51*, 1–12. https://doi.org/10.1016/j.esr.2024.101294

Elmahdi, A. (2024). Addressing water scarcity in agricultural irrigation: By exploring alternative water resources for sustainable irrigated agriculture. *Irrigation and Drainage, 73*(5), 1675–1683. https://doi.org/10.1002/ird.2973

Everard, M. (2018). Flood recession agriculture: Case studies. In C. Finlayson et al. (Eds.), *The wetland book* (pp. 1–14). Springer. https://doi.org/10.1007/978-90-481-9659-3_197

Falchetta, G., Semeria, F., Tuninetti, M., Giordano, V., Pachauri, S., & Byers, E. (2023). Solar irrigation in sub-Saharan Africa: Economic feasibility and development potential. *Environmental Research Letters*, *18*(9), 1–15. https://doi.org/10.1088/1748-9326/acefe5

Faurès, J. M., Svendsen, M., Turral, H., Berkoff, J., Bhattarai, M., Caliz, A. M., Darghouth, S., Doukkali, M. R., El-Kady, M., Facon, T., Gopalakrishnan, M., Groenfeldt, D., Hoanh, C. T., Hussain, I., Jamin, J., Konradsen, F., León, A., Meinzen-Dick, R., Miller, K., Mirza, M., Ringler, C., Schipper, L., Senzanje, A., Tadesse, G., Tharme, R., Hofwegen, P., Wahaj, R., Varela-Ortega, C., Yoder, R., & Zhanyi, G. (2013). Reinventing irrigation. In D. Molden (Ed.), *Water for food, water for life: A comprehensive assessment of water management in agriculture* (1st ed., pp. 353–394). Routledge. https://doi.org/10.4324/9781849773799

Ferrari-Toniolo, S., Bujold, P. M., Grabenhorst, F., Báez-Mendoza, R., & Schultz, W. (2020). Non-human primates satisfy utility maximization in compliance with the continuity axiom of expected utility theory. *bioRxiv*. https://doi.org/10.1101/2020.02.18.953950

File, D. J. M. B., Jarawura, F. X., & Derbile, E. K. (2023). Adapting to climate change: Perspectives from smallholder farmers in north-western Ghana. *Cogent Social Sciences*, *9*(1), 2228064. https://doi.org/10.1080/23311886.2023.2228064

Fischer, C., Aubron, C., Trouvé, A., Sekhar, M., & Ruiz, L. (2022). Groundwater irrigation reduces overall poverty but increases socioeconomic vulnerability in a semiarid region of southern India. *Scientific Reports*, *12*(1), 8850. https://doi.org/10.1038/s41598-022-12814-0

Frey, B. S., & Stutzer, A. (2014). Economic consequences of mispredicting utility. *Journal of Happiness Studies*, *15*, 937–956. https://doi.org/10.1007/s10902-013-9457-4

Gavrilets, S., Tverskoi, D., & Sánchez, A. (2024). Modelling social norms: An integration of the norm-utility approach with beliefs dynamics. *Philosophical Transactions of the Royal Society B*, *379*(1897), Article 20230027. https://doi.org/10.1098/rstb.2023.0027

Gazey, C., & Davies, S. (2009). *Soil acidity: A guide for WA farmers and consultants* (Bulletin No. 4784). Department of Primary Industries and Regional Development, Western Australia. https://library.dpird.wa.gov.au/bulletins/31

Ghana Statistical Service. (2014). *2010 population & housing census report: Disability in Ghana*. Ghana Statistical Service.

Ghana Statistical Service. (2021a). *Ghana 2021 population and housing census: General report volume 3A – Population of regions and districts*. https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203A_Population%20of%20Regions%20and%20Districts_181121.pdf

Ghana Statistical Service. (2021b). *2021 Population and Housing Census: General report volume 3A – Population of regions and districts*. https://census2021.statsghana.gov.gh/gssmain/fileUpload/reportthemelist/Volume%203%20Highlights.pdf

GIZ. (2012). *Growing business with smallholders: Guide to inclusive agribusiness*. GIZ. http://www.bmz.de

Gosling, S. N., & Arnell, N. W. (2016). A global assessment of the impact of climate change on water scarcity. *Climatic Change*, *134*, 371–385. https://doi.org/10.1007/s10584-013-0853-x

Guba, B. Y., Fielmua, N., & Mwingyine, D. T. (2023). Multiple-use water systems and rural livelihoods in north-western Ghana: Adjusting to a failed hope. *Water International*, *48*(4), 444–460. https://doi.org/10.1080/02508060.2023.2209502

Hansson, S. O. (2022). John Stuart Mill and the conflicts of equality. *The Journal of Ethics*, *26*(3), 433–453. https://doi.org/10.1007/s10892-022-09393-7

Herrick, J. E., Neff, J., Quandt, A., Salley, S., Maynard, J., Ganguli, A., & Bestelmeyer, B. (2019). Prioritizing land for investments based on short- and long-term land potential and degradation risk: A strategic approach. *Environmental Science & Policy*, *96*, 52–58. https://doi.org/10.1016/j.envsci.2019.03.001

Janssen, S., & Van Ittersum, M. K. (2007). Assessing farm innovations and responses to policies: A review of bio-economic farm models. *Agricultural Systems*, *94*(3), 622–636. https://doi.org/10.1016/j.agsy.2007.03.001

Jevons, W. S. (1871). *The theory of political economy*. Macmillan and Co. https://doi.org/10.1057/9781137374158

Karimi, F., Ghahderijani, M., & Bakhoda, H. (2024). Optimizing cropping patterns and resource allocation for sustainable agricultural development: A case study of Ilam province, Iran. *Environmental and Sustainability Indicators*, *23*, Article 100464. https://doi.org/10.1016/j.indic.2024.100464

Katic, P., & Ellis, T. (2018). Risk aversion in agricultural water management investments in Northern Ghana: Experimental evidence. *Agricultural Economics*, *49*(5), 575–586. https://doi.org/10.1111/agec.12443

Kemeze, F. H., Miranda, M. J., Kuwornu, J. K., & Anim-Somuah, H. (2020). Smallholder farmer risk preferences in northern Ghana: Evidence from a controlled field experiment. *The Journal of Development Studies*, *55*(10), 1894–1908. https://doi.org/10.1080/00220388.2020.1715945

Kheybari, S., Mehrpour, M. R., Bauer, P., & Ishizaka, A. (2024). How can risk-averse and risk-taking approaches be considered in a group multi-criteria decision-making problem? *Group Decision and Negotiation*, *33*(4), 883–909. https://doi.org/10.1007/s10726-024-09895-9

Klutse, N. A. B., Owusu, K., Nkrumah, F., & Anang, O. A. (2021). Projected rainfall changes and their implications for rainfed agriculture in northern Ghana. *Weather*, *76*(10), 340–347. https://doi.org/10.1002/wea.4015

Knox, J. W., Kay, M. G., & Weatherhead, E. K. (2012). Water regulation, crop production, and agricultural water management—Understanding farmer perspectives on irrigation efficiency. *Agricultural Water Management*, *108*, 3–8.

Koku, J. E. (2001). Socio-cultural factors and land degradation in the South Tongu District of Ghana: Some implications for resource protection and environmental health. *Journal of Environmental Planning and Management, 44*(3), 309–330. https://doi.org/10.1080/09640560120046089

Koku, J. E., & Gustafsson, J. E. (2003). Local institutions and natural resource management in the South Tongu district of Ghana: A case study. *Sustainable Development, 11*(1), 17–35. https://doi.org/10.1002/sd.201

Koundouri, P., Nauges, C., & Tchoupo, M. (2006). Determinants of farmers' decisions to adopt irrigation technologies in the face of climate change. *Environmental Economics and Policy Studies, 7*(4), 127–141. https://doi.org/10.1007/s10018-005-0196-4

Lahiri, S. (2020). Consumer surplus and budget constrained preference maximization: A note. *Managerial Economics, 21*(1), 49–65. https://doi.org/10.7494/manage.2020.21.1.49

Lehmann, N., Briner, S., & Finger, R. (2013). The impact of climate and price risks on agricultural land use and crop management decisions. *Land Use Policy, 35*, 119–130.

Lejarraga, T., & Hertwig, R. (2022). Three theories of choice and their psychology of losses. *Perspectives on Psychological Science, 17*(2), 334–345. https://doi.org/10.1177/17456916211001332

Levy, I., Snell, J., Nelson, A. J., Rustichini, A., & Glimcher, P. W. (2010). Neural representation of subjective value under risk and ambiguity. *Journal of Neurophysiology, 103*(2), 1036–1047. https://doi.org/10.1152/jn.00853.2009

Liersch, S., Koch, H., Abungba, J. A., Salack, S., & Hattermann, F. F. (2023). Attributing synergies and trade-offs in water resources planning and management in the Volta River basin under climate change. *Environmental Research Letters, 18*(1), 1–28. https://doi.org/10.1088/1748-9326/acad14

Liu, J., Fang, Y., Wang, G., Liu, B., & Wang, R. (2023). The aging of farmers and its challenges for labor-intensive agriculture in China: A perspective on farmland transfer plans for farmers' retirement. *Journal of Rural Studies, 100*, 1–14. https://doi.org/10.1016/j.jrurstud.2023.103013

Liu, Y., Chen, M., Yu, J., & Wang, X. (2024). Being a happy farmer: Technology adoption and subjective well-being. *Journal of Economic Behavior & Organization, 221*, 385–405.

Loewenstein, G., & Ubel, P. A. (2008). Hedonic adaptation and the role of decision and experience utility in public policy. *Journal of Public Economics, 92*(8–9), 1795–1810. https://doi.org/10.1016/j.jpubeco.2007.12.011

Long, D. G. (2017). 'Utility' and the 'utility principle': Hume, Smith, Bentham, Mill. In *Jeremy Bentham* (pp. 3–30). Routledge.

Makate, C. (2020). Local institutions and indigenous knowledge in adoption and scaling of climate-smart agricultural innovations among sub-Saharan smallholder farmers. *International Journal of Climate Change Strategies and Management, 12*(2), 270–287. https://doi.org/10.1108/IJCCSM-07-2018-0055

Maleksaeidi, H., Keshavarz, M., Karami, E., & Eslamian, S. (2017). Climate change and drought: Building resilience for an unpredictable future. In S. Eslamian & F. Eslamian (Eds.), *Handbook of drought and water scarcity: Environmental impacts and analysis of drought and water scarcity* (pp. 163–186). CRC Press. https://doi.org/10.1201/9781315226781

Manasseh, C. O., Logan, C. S., Okanya, O. C., Igwemeka, E., Odidi, O., Onoh, C. F., ... & Ejim, E. P. (2025). The nexus between electricity generation and agricultural development in Africa. *International Journal of Energy Economics and Policy*, *15*(1), 317–329. https://doi.org/10.32479/ijeep.14651

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2018). Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. *Land*, *7*(2), 49. https://doi.org/10.3390/land7020049

Martey, E., Etwire, P. M., & Abdoulaye, T. (2025). Agricultural commercialization and sustainable land management practices in Ghana. *Environment, Development and Sustainability*, 1–26. https://doi.org/10.1007/s10668-025-06121-7

McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: Initial changes and continuing challenges. *Ecology and Society*, *19*(2). https://doi.org/10.5751/es-06387-190230

Mensah, J. V., Tamakloe, W. A., & Essaw, D. W. (2018). Poverty reduction programmes and sustainable livelihoods in the South Tongu District in Ghana. *Management Today*, *8*(3), 221-231. http://dx.doi.org/10.11127/gmt.2018.09.02

Ministry of Food and Agriculture (MoFA). (2021). *Asunafo North Municipal*. http://mofa.gov.gh/site/directorates/district-directorates/brong-ahafo-region/138-asunafo-north-municipal

Monteiro, M. A., Bahta, Y. T., & Jordaan, H. (2024). A systematic review on drivers of water-use behavior among agricultural water users. *Water*, *16*(13), 1899. https://doi.org/10.3390/w16131899

Moscati, I. (2019). *Measuring utility: From the marginal revolution to behavioral economics*. Oxford University Press.

Mukhtorov, U., Sultanov, B., Ismailov, T., & Rustamov, J. (2023). Innovative organization and increase of efficiency of agricultural melioration measures of Uzbekistan. In *E3S Web of Conferences*, *386*, 1-8. EDP Sciences. https://doi.org/10.1051/e3sconf/202338603009

Müller, T. (2021). Measuring utility: From the marginal revolution to behavioural economics. *European Journal of The History of Economic Thought*, *28*(3), 492–493. https://doi.org/10.1080/09672567.2021.1893911

Mulligan, K., Baid, D., Doctor, J. N., Phelps, C. E., & Lakdawalla, D. N. (2024). Risk preferences over health: Empirical estimates and implications for medical decision-making. *Journal of Health Economics*, *94*, 1-24. https://doi.org/10.1016/j.jhealeco.2024.102857

Mupaso, N., Makombe, G., Mugandani, R., & Mafongoya, P. L. (2024). Assessing the contribution of smallholder irrigation to household food security in Zimbabwe. *Agriculture*, *14*(4), 617. https://doi.org/10.3390/agriculture14040617

Musshoff, O., & Hirschauer, N. (2011). A behavioral economic analysis of bounded rationality in farm financing decisions: First empirical evidence. *Agricultural Finance Review*, *71*(1), 62-83.

Namara, R. E., Hope, L., Sarpong, E. O., De Fraiture, C., & Owusu, D. (2014). Adoption patterns and constraints pertaining to small-scale water lifting technologies in Ghana. *Agricultural Water Management*, *131*, 194-203. https://doi.org/10.1016/j.agwat.2013.08.023

Nchanji, E. B., Chagomoka, T., Bellwood-Howard, I., Drescher, A., Schareika, N., & Schlesinger, J. (2023). Land tenure, food security, gender and urbanization in Northern Ghana. *Land Use Policy*, *132*, 1-12. https://doi.org/10.1016/j.landusepol.2023.106834

Newman, A. C. D. (1984). The significance of clays in agriculture and soils. *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*, *311*(1517), 375-389. https://doi.org/10.1098/rsta.1984.0035

Nikoi, E., & Alorbu, V. (2023). A study of residents' perception towards main water sources along the Volta River: The case of South Tongu District. *International Journal of Applied Research in Social Sciences*, *5*(1), 14–28. https://doi.org/10.51594/ijarss.v5i1.446

Noort, M. W., Renzetti, S., Linderhof, V., du Rand, G. E., Marx-Pienaar, N. J., de Kock, H. L., … Taylor, J. R. (2022). Towards sustainable shifts to healthy diets and food security in sub-Saharan Africa with climate-resilient crops in bread-type products: A food system analysis. *Foods*, *11*(2), 135.

Nyantakyi-Frimpong, H., Dinko, D. H., & Kerr, R. B. (2023). Floodplain farming and maladaptation to extreme rainfall events in northern Ghana. *Climate and Development*, *15*(3), 201–214. https://doi.org/10.1080/17565529.2022.2074953

Ofori, S. A., Cobbina, S. J., & Obiri, S. (2021). Climate change, land, water, and food security: Perspectives from Sub-Saharan Africa. *Frontiers in Sustainable Food Systems*, *5*, 1–9. https://doi.org/10.3389/fsufs.2021.680924

Osei, V. (2015). Water resources management and agricultural productivity in Ghana. *Journal of Agricultural Economics*, *46*(3), 299–314. https://doi.org/10.2139/ssrn.2354715

Otokunor, P. B., Onumah, E. E., Bruce-Sarpong, D., & Anaman, K. A. (2023). Determinants of competitiveness of irrigated and rain-fed tomato production technologies in Ghana. *International Journal of Agricultural Policy and Research*, *11*(3), 1–12. https://doi.org/10.15739/IJAPR.23.009

Pereira, D., Leitao, J. C. C., Gaspar, P. D., Fael, C., Falorca, I., Khairy, W., … Cutajar, J. (2023). Exploring irrigation and water supply technologies for smallholder farmers in the Mediterranean region. *Sustainability*, *15*(8), 1–25. https://doi.org/10.3390/su15086875

Peters, M. K., & Kusimi, J. M. (2023). Changes in wetland and other landscape elements of the Keta Municipal area of Ghana. *Journal of Coastal Conservation, 27*(1), Article 1. https://doi.org/10.1007/s11852-022-00928-6

Pratiwi, E. W., Negoro, T., & Haykal, H. (2022). Teori utilitarianisme Jeremy Bentham: Tujuan hukum atau metode pengujian produk hukum? *Jurnal Konstitusi*, *19*(2), 268. https://doi.org/10.31078/jk1922

Puranam, P., Stieglitz, N., Osman, M., & Pillutla, M. M. (2015). Modelling bounded rationality in organizations: Progress and prospects. *Academy of Management Annals*, *9*(1), 337–392.

Raja, K. M., & Alias, M. S. (2024). Assessing John Stuart Mill's principle of utility: Barrier or bridge to equality? *International Journal of Research and Innovation in Social Science*, *8*(9), 1973–1983. https://doi.org/10.47772/IJRISS.2024.8090163

Ramoglou, S., Jayasekera, R., & Soobaroyen, T. (2025). Do policymakers mean what they say? Symbolic pressures and the subtle dynamics of the institutional game. *Academy of Management Perspectives, 39*(2), 290–311.

Ringler, C., Mekonnen, D., Xie, H., & Uhunamure, A. M. (2020). Irrigation to transform agriculture and food systems in Africa south of the Sahara. *Research Papers in Economics, 1*(2020), 57–70. https://EconPapers.repec.org/RePEc:fpr:ifpric:9780896293946_06

Robert, M., Thomas, A., & Bergez, J. E. (2016). Processes of adaptation in farm decision-making models: A review. *Agronomy for Sustainable Development*, *36*(64), 1–15. https://doi.org/10.1007/s13593-016-0402-x

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2018). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Sall, M., Poussin, J. C., Bossa, A. Y., Ndiaye, R., Cissé, M., Martin, D., … Ogilvie, A. (2020). Water constraints and flood-recession agriculture in the Senegal river valley. *Atmosphere*, *11*(11), 1192. https://doi.org/10.3390/atmos11111192

Sarku, R. (2023). Farmers' perspectives on water availability in the lower Volta Delta region in Ghana. *Regional Environmental Change, 23*(4), 163. https://doi.org/10.1007/s10113-023-02152-w

Sarku, R., Dewulf, A., van Slobbe, E., Termeer, K., & Kranjac-Berisavljevic, G. (2020). Adaptive decision-making under conditions of uncertainty: The case of farming in the Volta delta, Ghana. *Journal of Integrative Environmental Sciences, 17*(1), 1–33. https://doi.org/10.1080/1943815X.2020.1729207

Savari, M., Damaneh, H. E., Damaneh, H. E., & Cotton, M. (2023). Integrating the norm activation model and theory of planned behaviour to investigate farmer pro-environmental behavioural intention. *Scientific Reports, 13*(1), 5584.

Schulze, C., Zagórska, K., Häfner, K., Markiewicz, O., Czajkowski, M., & Matzdorf, B. (2024). Using farmers' ex ante preferences to design agri-environmental contracts: A systematic review. *Journal of Agricultural Economics*, *75*(1), 44–83. https://doi.org/10.1111/1477-9552.12570

Serote, B., Mokgehle, S., Senyolo, G., du Plooy, C., Hlophe-Ginindza, S., Mpandeli, S., ... & Araya, H. (2023). Exploring the barriers to the adoption of climate-smart irrigation technologies for sustainable crop productivity by smallholder farmers: Evidence from South Africa. *Agriculture*, *13*(2), 246. https://doi.org/10.3390/agriculture13020246

Shah, T., Namara, R., & Rajan, A. (2020). Accelerating irrigation expansion in Sub-Saharan Africa: Policy lessons from the global revolution in farmer-led smallholder irrigation. World Bank. https://hdl.handle.net/10986/35804

Shahzad, A. R., Fatima, N., & Saleem, M. (2024). Mobile phones in agriculture: Understanding the role of perceived awareness in shaping farmers' adoption decisions in Punjab, Pakistan. *Pakistan Social Sciences Review, 8*(3), 732–741. https://doi.org/10.35484/pssr.2024(8-III)59

Siderius, C., van der Velde, Y., Gülpen, M., de Bruin, S., & Biemans, H. (2024). Improved water management can increase food self-sufficiency in urban foodsheds of Sub-Saharan Africa. *Global Food Security, 42*, 1–13. https://doi.org/10.1016/j.gfs.2024.100787

Sims, C. R., Neth, H., Jacobs, R. A., & Gray, W. D. (2013). Melioration as rational choice: Sequential decision making in uncertain environments. *Psychological Review, 120*(1), 1–16. https://doi.org/10.1037/a0030850

Singh, C., Dorward, P., & Osbahr, H. (2016). Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. *Land Use Policy*, *59*, 329–343. https://doi.org/10.1016/j.landusepol.2016.06.041

Sinha, S. (2020). Theory of utility and the modern legislation: A study of application of Bentham's utilitarian theory. *JL Science & Cultural Journal, 1*(1). https://www.royalliteglobal.com/jlscj/article/download/128/161

Smith, J. E., & Ulu, C. (2017). Risk aversion, information acquisition, and technology adoption. *Operations Research*, *65*(4), 1011–1028. https://doi.org/10.1287/opre.2017.1601

Smits, W. K., Attoh, E. M., & Ludwig, F. (2024). Flood risk assessment and adaptation under changing climate for the agricultural system in the Ghanaian White Volta Basin. *Climatic Change*, *177*(3), 1–24. https://doi.org/10.1007/s10584-024-03694-6

Sommer, R., Bossio, D., Desta, L., Dimes, J., Kihara, J., Koala, S., Mango, N., Rodriguez, D., Thierfelder, C., & Winowiecki, L. (2013). Profitable and sustainable nutrient management systems for East and Southern African smallholder farming systems: Challenges and opportunities. CIAT, QAAFI, The University of Queensland. https://repository.cimmyt.org/server/api/core/bitstreams/6e2d1827-0414-4b3a-ab12-0b3847bd3915/content

South Tongu District Assembly. (1996). *South Tongu District socio-economic survey*. SPRING/Department of Planning, University of Science and Technology, Ghana.

South Tongu District Assembly. (2021). *Annual progress report*. https://ndpc.gov.gh/media/VR_South_Tongu_APR_2020.pdf

Sun, D., Addae, E. A., Jemmali, H., Mensah, I. A., Musah, M., Mensah, C. N., & Appiah-Twum, F. (2021). Examining the determinants of water resources availability in sub-Sahara Africa: A panel-based econometrics analysis. *Environmental Science and Pollution Research*, *28*, 21212–21230. https://doi.org/10.1007/s11356-020-12256-z

Suri, M. R., Dery, J. L., Pérodin, J., Brassill, N., He, X., Ammons, S., Gerdes, M. E., Rock, C., Rosenberg Goldstein, R. E., & Rosenberg Goldstein, R. E. (2019). U.S. farmers' opinions on the use of nontraditional water sources for agricultural activities. *Environmental Research*, *172*, 345–357. https://doi.org/10.1016/J.ENVRES.2019.02.035

Svendsen, M., Johnson, S., Brown, P., Kolavalli, S., & Dittoh, S. (2011). *Strategic issues for irrigation development in Ghana* (GSSP Working Paper No. 23). International Food Policy Research Institute (IFPRI).

Tack, J., Barkley, A., & Hendricks, N. (2017). Irrigation offsets wheat yield reductions from warming temperatures. *Environmental Research Letters*, *12*(11), 114027. https://doi.org/10.1088/1748-9326/aa8d27

Tai, X., Feng, F., & Sun, F. (2024). Farmers' willingness and adoption of water-saving agriculture in arid areas: Evidence from China. *Sustainability*, *16*(18), 8112. https://doi.org/10.3390/su16188112

Tesfaye, M. Z., Balana, B. B., & Bizimana, J. C. (2021). Assessment of smallholder farmers' demand for and adoption constraints to small-scale irrigation technologies: Evidence from Ethiopia. *Agricultural Water Management*, *250*, 106855. https://doi.org/10.1016/j.agwat.2021.106855

Tey, Y. S., & Brindal, M. (2015). Factors influencing farm profitability. In E. Lichtfouse (Ed.), *Sustainable agriculture reviews* (Vol. 15, pp. 235–255). Springer. https://doi.org/10.1007/978-3-319-09132-7_5

Tian, M., Liu, R., Wang, J., Liang, J., Nian, Y., & Ma, H. (2023). **Impact of environmental** values and information awareness on the adoption of soil testing and formula fertilization technology by farmers—A case study considering social networks. *Agriculture, 13*(10), 2008.

Touch, V., Tan, D. K., Cook, B. R., Liu, D. L., Cross, R., Tran, T. A., Utomo, A., Yous, S., Grunbuhel, C., & Cowie, A. (2024). Smallholder farmers' challenges and opportunities: Implications of agricultural production, environment and food security. *Journal of Environmental Management, 370*, 122536. https://doi.org/10.1016/j.jenvman.2024.122536

Tuffour, M., Sedegah, D. D., & Asiama, R. K. (2023). Seasonal water sources at irrigated urban vegetable production sites in Ghana. *Irrigation and Drainage*, *72*(3), 864–879. https://doi.org/10.1002/ird.2814

Ullah, I., Khan, N., Dai, Y., & Hamza, A. (2023). Does solar-powered irrigation system usage increase the technical efficiency of crop production? New insights from rural areas. *Energies*, *16*(18), 1–16. https://doi.org/10.3390/en16186641

Umar, B. B. (2014). A critical review and re-assessment of theories of smallholder decision-making: A case of conservation agriculture households, Zambia. *Renewable Agriculture and Food Systems*, *29*(3), 277–290. https://doi.org/10.1017/S1742170513000148

Umer, Y., Chavula, P., Abdi, E., Ahamad, S., Lungu, G., Abdula, H., ... & Ahmed, S. (2024). Small-scale irrigation farming as a climate-smart agriculture practice; its adoption and impact on food security for Ethiopian smallholder farmers: A review. *Asian Research Journal of Current Science,* *6*(1), 163–180. https://prh.globalpresshub.com/review-history/1638

Urfels, A., Mausch, K., Harris, D., McDonald, A. J., Kishore, A., Singh, B., van Halsema, G., Struik, P. C., Craufurd, P., Foster, T. J., Singh, V., & Krupnik, T. J. (2023). Farm size limits agriculture's poverty reduction potential in Eastern India even with irrigation-led intensification. *Agricultural Systems*, *207*, 103618. https://doi.org/10.1016/j.agsy.2023.103618

Wahab, I., Hall, O., & Jirström, M. (2022). "The maize is the cost of the farming, and the cassava is our profit": Smallholders' perceptions and attitudes to poor crop patches in the eastern region of Ghana. *Agriculture & Food Security*, *11*(1), 14. https://doi.org/10.1186/s40066-022-00361-w

Ward, F. A. (2010). Financing irrigation water management and infrastructure: A review. *International Journal of Water Resources Development*, *26*(3), 321–349. https://doi.org/10.1080/07900627.2010.489308

Xi, X., & Zhang, J. (2020). Complexity analysis of a decision-making game concerning governments and heterogeneous agricultural enterprises with bounded rationality. *Chaos, Solitons & Fractals*, *140*, 110220. https://doi.org/10.1016/j.chaos.2020.110220

Yan, F., Fu, Y., Paradelo, M., Zhang, F., & Arthur, E. (2023). Long-term manure and cropping systems effect on soil water vapour sorption characteristics is controlled by soil texture. *Geoderma*, *436*, 116533. https://doi.org/10.1016/j.geoderma.2023.116533

Yang, Y., Jin, Z., Mueller, N. D., Driscoll, A. W., Hernandez, R. R., Grodsky, S. M., ... & Lobell, D. B. (2023). Sustainable irrigation and climate feedbacks. *Nature Food*, *4*(8), 654–663. https://doi.org/10.1038/s43016-023-00821-x

Yeleliere, E., Antwi-Agyei, P., & Baffour-Ata, F. (2023). Impacts of climate change on the yields of leguminous crops in the Guinea Savanna agroecological zone of Ghana. *Regional Sustainability*, *4*(2), 139–149. https://doi.org/10.1016/j.regsus.2023.04.002

Yiridomoh, G. Y., Sullo, C., & Bonye, S. Z. (2021). Climate variability and rural livelihood sustainability: Evidence from communities along the Black Volta River in Ghana. *GeoJournal*, *86*(4), 1527–1543. https://doi.org/10.1007/S10708-020-10144-0