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RELIABLE IRRIGATION WATER ACCESS FOR SMALLHOLDER FARMERS IN GHANA: A SYSTEMATIC REVIEW

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ABSTRACT

Reliable access to irrigation water from available sources is crucial for smallholder farmers in Sub-Saharan African countries, including Ghana. Such access is expected to mitigate the adverse impacts of climate change on agricultural productivity and crop yield. Irrigation water access is supposed to foster economic and income growth. However, in Ghana, past studies have indicated that the mean annual temperature is expected to increase in the future. This rise in temperature is likely to lead to a significant reduction in crop yield and increased food insecurity. We argue that while smallholder farmers are eager to use irrigation on their fields, they lack a dependable source of water for irrigation. Water access is inconsistent, regardless of whether there is a source of water. Smallholder farmers face persistent challenges in accessing reliable irrigation water, largely due to inadequate capital investment in irrigation infrastructure and limited technical and financial support from the government. While these barriers are well acknowledged, there is limited empirical study focused on identifying why irrigation has underperformed in Ghana. Therefore, this paper investigates the reliability of irrigation water access for smallholder farmers in Ghana. In this paper, we used the PRISMA method to conduct a systematic literature review from November 2022 to June 2025. Our primary sources of information for this review were the electronic journal databases of JSTOR and Google Scholar. The inclusion criteria for our study were restricted to journal articles published in English from 2010 to 2024. Using keywords like "reliable water access," "smallholder farmers," "water sources," and "irrigation," we narrowed down our search and found 17,325 items. Of the 17,325 articles, the focus of 56 was on our objective, and the 56 articles were about Ghana. As a result, we found that Ghana has the potential to develop dependable irrigation schemes and implement reliable irrigation systems for agricultural production. However, there is insufficient irrigation in the agricultural sector, which is mostly rainfed. We discovered that inadequate and inconsistent water access caused low productivity, low yields, food insecurity, and poor livelihoods. Additionally, crops suffer damage and farms flood because of the unpredictable rainfall pattern and inadequate water storage facilities. This study will help inform policy interventions for reliable, consistent, and efficient water use in agricultural irrigation and strengthen resilience to climate variability.

Keywords: Smallholder farmers, Water sources, Reliable water access, Irrigation, Ghana

1. INTRODUCTION

The unreliable irrigation water access is a challenge faced by agricultural communities in Sub-Saharan Africa (Foster et al., 2020; Niasse & Varis, 2020). This challenge was attributed to rising temperatures, erratic rainfall patterns, socio-economic constraints, and insufficient investment (Callo-Concha et al., 2013; Xenarios et al., 2019). Past studies have shown that insufficient investment in water storage facilities limited access to irrigation (Giordano et al., 2012; Nakawuka et al., 2018). Some studies emphasized the need for concerted efforts among stakeholders in funding the agricultural sector to store and make irrigation water access reliable for smallholder farming (Cosgrove & Loucks, 2015). Other studies revealed that erratic and unpredictable rainfall patterns threaten the storage and reliable access of irrigation water (Garg et al., 2024; Sinore & Wang, 2025). For instance, floods sometimes occur and damage farms and infrastructure from which water is accessed for smallholder farming (Bremond et al., 2013; Nam & Choi, 2014). Additionally, rising temperatures make water sources vulnerable to drought and affect water access for smallholders and their communities (Lottering et al., 2021). Furthermore, farmers' interest in having access to irrigation water is greatly influenced by their income and level of education (Asayehegn et al., 2011).

In Ghana, studies proposed to introduce rainwater harvesting, drip, and sprinkler irrigation systems for smallholder farmers (Darko et al., 2020; Hanjra & Williams, 2020; Xie et al., 2018). Over the last ten years, the Ghanaian government's attention has shifted to the use of water resources and agricultural water productivity as integral components of the decision-making process for enhancing food security through improved access to irrigation water (Bieber et al., 2018; Naab et al., 2019; Nalumu et al., 2021). As a result, the government decided to build dams and reservoirs as part of the "one village, one dam" flagship program to make irrigation water accessible for farming communities (Balana & Akudugu, 2023; Kemeze, 2020). The government came up with this initiative to mitigate the telling effects of climate change and the overdependence on rain-fed food production, which was risky and unsustainable (Dittoh, 2020). However, there were challenges in securing adequate capital for this project. Budget constraints, limited funding, and bureaucratic hurdles became significant challenges for the development of these irrigation projects. Studies have shown that the astronomical construction costs of irrigation facilities and

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funding allocation were often competitive with other sectors of Ghana's economy (Giordano & De Fraiture, 2014; Namara et al., 2011).

According to a study by Enriquez et al. (2021), it might be more likely to practice alternate wetting and drying for rice cultivation if farmers have reliable irrigation water access from sources such as rivers, streams, and reservoirs. A study by Poussin et al. (2015) indicated that having access to reliable irrigation water sources, as mentioned, could significantly enhance smallholder farming. Some studies have shown that reliable irrigation water access from available water sources could contribute to sustainable soil management, enhance the use of fertilizers, facilitate continuous cropping, and improve agricultural production (Greaves & Wang, 2017). For instance, a study on agricultural water usage in China by Jin and Young (2001) indicated that 40% of irrigated land accounted for 75% of grain production. Other studies showed that appropriate soil moisture content helped plants absorb nutrients and that vegetable crops required consistent and adequate access to both water and nutrients (Gopalakrishnan, 2007; Jat et al., 2011; Karthika et al., 2018). Additionally, if soil water tension remains above 25 kPa for several hours, plant growth and yields will reduce (Bianchi et al., 2017; Smittle & Dickens, 1992). Therefore, the unreliable nature of irrigation water access is a major production risk for Ghanaian smallholder farmers (Koide et al., 2021; Qadir et al., 2010).

Past studies have demonstrated that the irrigation sector in Ghana has not yet played a major role in covering the imbalance between food demand and supply to benefit farmers (Hanjra & Williams, 2020; Sakho-Jimbira & Hathie, 2020). Some studies revealed that donors and decision-makers were aware that Ghana has significant land and water potential for any agricultural venture (Aarnoudse et al., 2018; Namara et al., 2011; Pavelic et al., 2013). Other studies indicated that irrigation water could be sourced from the Volta River Basin, groundwater, and stored water in natural and built infrastructure or reservoirs (Balana et al., 2020; Johnston & McCartney, 2010; Payen et al., 2019). Farmers are interested in adopting irrigation on their farms (Tesfaye et al., 2021). However, they do not have reliable irrigation water access for their farms from the various water sources available (Aidam, 2015; Akudugu et al., 2021). Still, they rely on rainfall. A gap, therefore, remains in answering why irrigation has performed well in some countries, but the districts along the Volta River Basin and other water catchment areas in Ghana continue to struggle. It is against this backdrop that this paper attempts to investigate the reliable irrigation water access for smallholder farmers in Ghana. Filling this knowledge gap in existing literature and raising public awareness about reliable irrigation water access for smallholder farming is crucial to mitigate climate change effects on agriculture in the future.

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2. LITERATURE REVIEW

Globally, smallholder farmers rely on a variety of water sources for irrigation (Pereira et al., 2023), including surface water from rivers, lakes, and ponds, and groundwater from wells and boreholes (Andrezejewski, 2014; Yoshikawa et al., 2014). In China, some farmers utilize rainwater harvesting and treated wastewater (Balata et al., 2022). In high-rainfall regions, farmers rely on surface water and harvested rainwater (Noori & Singh, 2023), whereas in arid and semi-arid areas, groundwater serves as a more stable irrigation source when surface water is limited (Alfarrah & Walraevens, 2018; Priyan, 2021). However, in Sub-Saharan African countries, including Ghana, farmers face challenges in accessing reliable irrigation water (Nalumu et al., 2021). Some studies attributed farmers' unreliable irrigation water access to rising temperatures, erratic rainfall patterns, socio-economic constraints, and poor irrigation infrastructure (Arfasa et al., 2024). Studies by Agodzo et al. (2023) and Akudugu et al. (2021) identified water availability and climate conditions as determining factors for farmers' reliable irrigation water access. Anang and Asante (2020) found that in Northern Ghana, farmers' physical and socio-economic conditions influenced irrigation water access. Yussif et al. (2015) found that limited credit support in the agricultural water sector negatively influenced farmers' irrigation water access. Islam et al. (2023) emphasized the importance of integrated water resource management, technological innovation, and supportive policies to ensure equitable water access for farmers.

Along the Lower Volta River Basin of Ghana, the existing infrastructure for irrigation falls short of meeting the demands of smallholder farming (Balana et al., 2020; Baldwin & Stwalley, 2022). Poor water storage facilities limited the reliability of irrigation technologies (Giordano et al., 2012; Nakawuka et al., 2018). Moreover, farmers encountered difficulties in obtaining adequate water during dry seasons (Sarku et al., 2020). This further heightened the constraints of existing irrigation methods, as found by past studies highlighted in Table 1. Farmers were unable to maximize their yields and were at risk of food insecurity due to inadequate water storage and distribution infrastructure (Balana et al., 2020; Darko et al., 2020; Sarku, 2023).

Drip and sprinkler irrigation systems might ensure reliable irrigation water access for farmers (Amankwah-Yeboah et al., 2023). The adoption of these systems could unlock farmers' irrigation potential and enhance food security, livelihoods, and poverty reduction efforts (Dinye & Ayitio, 2013). However, despite potential benefits, the widespread adoption of drip and sprinkler irrigation systems in Ghana is limited. This is attributed to high initial costs, inadequate access to financing, and insufficient awareness among farmers, among other factors (Nakawuka et al., 2018). This highlights the need for government and development agencies to provide subsidies, training, and technical support to encourage farmers to adopt efficient irrigation systems (Bjornlund et al., 2017; Levidow et al., 2014).

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Recognizing the benefits of irrigation, the Ghanaian government prioritized improving access to irrigation water for agricultural productivity (Bieber et al., 2018; Naab et al., 2019; Nalumu et al., 2021). The "One-village-one-dam" flagship program was established to construct dams and reservoirs to enhance irrigation water accessibility (Balana & Akudugu, 2023; Kemeze, 2020). It also aims to mitigate the effects of climate change and reduce reliance on rain-fed food production (Dittoh, 2020). However, the program faced budget constraints, bureaucratic hurdles, high construction costs, and other competing government priorities (Giordano & De Fraiture, 2014; Namara et al., 2011).

Ghana had implemented the Food and Agriculture Sector Development Policy (FASDEP II) in the past to facilitate irrigation developments for farmers (Abdulai et al., 2024; Amponsah et al., 2023). This policy appeared to be promising with the hope of providing reliable irrigation water for beneficiary farmers (Kwao & Amoak, 2022). The policy aimed to improve agricultural productivity and yield by expanding the area under water management and the rural feeder road network. However, Connelly et al. (2017) noted in their report that no prior measures had addressed rural feeder roads. Additionally, limited access to technology, inadequate infrastructure, and challenges in value chain development were among the constraints faced by the FASDEP II.

The Medium-Term Agricultural Sector Investment Plan (METASIP) prioritized the small-scale irrigation sector in the short- and medium-term agriculture development plan (Boateng & Nyaaba, 2014). However, credit support from the government and inadequate investment, maintenance, and operation costs, among other factors, influenced farmers' irrigation water access in Ghana (Anang et al., 2015; Kyire et al., 2023). Additionally, the government has paid little attention to the small-scale irrigation schemes as compared to large-scale undertakings (Amponsah et al., 2023; Baldwin & Stwalley, 2022; Boateng & Nyaaba, 2014; Salifu & Salifu, 2024). Although studies have shown positive results from small-scale irrigation schemes (Bjornlund et al., 2017), access to reliable irrigation water for smallholder farming has been a challenge for decades (Ankrah et al., 2021). Therefore, improving access to water sources is crucial for ensuring reliable irrigation, minimizing the risk of crop failure, and sustaining farmers' livelihoods (Acheampong et al., 2018; Antwi-Agyei et al., 2014).

Table 1: Summary of Irrigation Water Access, Infrastructure, Policies, and Constraints

Review topics	Focus of past studies (irrigation)	Findings	Citations
Irrigation water access challenges	Irrigation water	Unreliable irrigation water access was due to rising temperatures, erratic rainfall patterns, socio-economic constraints, and poor irrigation infrastructure.	(Agodzo et al., 2023; Akudugu et al., 2021; Alfarrah & Walraevens, 2018; Anang & Asante, 2020; Andrezejewski, 2014; Arfasa et al., 2024; Balata et al., 2022; Bieber et al., 2018; Giordano & De Fraiture, 2014; Islam et al., 2023; Naab et al., 2019; Nakawuka et al., 2018; Nalumu et al., 2021; Namara et al., 2011; Noori & Singh, 2023; Pereira et al., 2023; Priyan, 2021; Sarku et al., 2020; Yoshikawa et al., 2014; Yussif et al., 2015)
Irrigation Infrastructure/Systems	Irrigation systems	Farmers experienced low yield and food insecurity due to inadequate water storage and distribution infrastructure.	(Amankwah-Yeboah et al., 2023; Balana et al., 2020; Baldwin & Stwalley, 2022; Darko et al., 2020; Dinye & Ayitio, 2013; Giordano et al., 2012; Nakawuka et al., 2018; Sarku, 2023)
Irrigation development policies and constraints	Irrigation development challenges	Agricultural productivity and outputs were anticipated to be improved with water management. However, the government has paid little attention to the small-scale irrigation schemes. The initiatives faced budget constraints, bureaucratic hurdles, and high construction costs. Limited access to technology and inadequate infrastructure were identified.	(Abdulai et al., 2024; Acheampong et al., 2018; Amponsah et al., 2023; Anang et al., 2015; Ankrah et al., 2021; Antwi-Agyei et al., 2014; Balana & Akudugu, 2023; Baldwin & Stwalley, 2022; Bieber et al., 2018; Bjornlund et al., 2017; Boateng & Nyaaba, 2014; Connelly et al., 2017; Dittoh, 2020; Giordano & De Fraiture, 2014; Kemeze, 2020; Kwao & Amoak, 2022; Kyire et al., 2023; Naab et al., 2019; Nalumu et al., 2021; Namara et al., 2011; Salifu & Salifu, 2024)

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3. METHODOLOGY

3.1 Data Collection and Analysis

In this study, we conducted a systematic literature review on reliable irrigation water access for smallholder farmers in Ghana from November 2022 to June 2025. We used the systematic literature review because it is a reliable and less biased review type that leads to evidence-based conclusions (Koutsos et al., 2019). For this study, we selected the Mardani et al. (2019) and Moher et al. (2009) preferred reporting items for systematic review and meta-analysis (PRISMA) method. However, we did not conduct meta-analysis in the study. In this PRISMA method, we included data sources, inclusion and exclusion criteria, steps of the review process, data abstraction and analysis, interpretation, and presentation processes (Koutsos et al., 2019). In this review, we searched for literature, determined articles' eligibility, extracted data, and then summarized the information obtained in sections that include investment in irrigation infrastructure, temperature and rainfall patterns, land tenure, and inadequate irrigation infrastructure development. Our primary sources of information for this review were electronic journal databases of JSTOR and Google Scholar.

We used a fixed set of inclusion criteria, which involved articles published in English from Ghana, limited to accessible journal articles published from 2010 to 2024 available in the selected databases. Our inclusion criteria were established through consultation with farmers, opinion leaders, and some stakeholders, depending on the key element of the systematic study. We also reviewed some literature in validating and establishing our inclusion criteria. We identified and tested the inclusion criteria through a pilot study. This was an essential step for finding relevant information and maintaining the specificity of the review.

We then followed the PRISMA screening procedure to report items in the systematic review. Our search was limited to keywords such as "reliable water access," "smallholder farming," "water sources," and "irrigation," resulting in the identification of 17,325 items, as shown in Table 2. Out of the 17,325 articles, the focus of 56 of them was on our objective. Therefore, we used 56 articles from Ghana for our review (Table 2). Equation 1 below illustrates the aggregation of the referenced articles (N = 56) for the review.

$$N_T = N_1 + N_2 \quad (1)$$

Where:

N_1 = number of articles identified from JSTOR (125)

N_2 = number of articles identified from Google Scholar (17,200)

N_T = total number of articles identified (17,325)

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The abstracts and relevant results were then exported into an Excel sheet for further reading, and tables were produced for discussion based on the review objective. As mentioned earlier, results were presented in sections that include investment in irrigation infrastructure, temperature and rainfall patterns, land tenure, and inadequate irrigation infrastructure development.

We present and briefly discuss the results of the systematic literature review as shown in Table 3. In doing so, we provided a summary of the most important results and discussions about reliable irrigation water access for smallholder farmers in Ghana. Based on the findings, we drew conclusions and then provided some suggestions to improve reliable irrigation water access for farmers. Furthermore, the investigation highlighted cases in the South Tongu district of Ghana's Volta Region. We highlighted the South Tongu district because of the water sources, agricultural activities, infrastructure, and potential for irrigation development. The South Tongu district lies along the Lower Volta River Basin and other water catchment areas.

Table 2: Systematic Review Flow for Database Search and Article Selection

	Articles identified through JSTOR, $N_1 = 125$	**Total number of articles identified, $N_T = 17,325$**	**Articles identified through Google Scholar, $N_2 = 17,200$**	**Articles excluded**
Identification		Title/Abstract/Keywords: Selected articles based on title, abstract, and keywords. N = 3,069		Excluded = 14,256
Screening		Article Title: Articles after duplication deleted. E.g., conference proceedings. N = 2986		Excluded = 83
Eligibility		Title and Abstract Reading: Articles not related to irrigation were deleted. N = 215		Excluded = 2,771
		Main Body Article Reading: Experimental articles, articles not related to irrigation systems management. N = 92		Excluded = 123
		Main body article reading: Articles with no clear focus on reliable irrigation water access. N = 56		Excluded = 36
Inclusion		Articles included in the systematic review. N = 56		

Source: Modified from Mardani et al. (2019) and Moher et al. (2009)

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4. RESULTS AND DISCUSSION

4.1 Investment in Irrigation Infrastructure

Our investigation revealed that Ghana possesses abundant water resources and has the capacity to make irrigation water accessible to farms (Table 3). Access to consistent irrigation water could be successful, as demonstrated in other countries such as China and India. This process requires institutional, financial, and technical support from the government, non-governmental organizations, and other stakeholders, as indicated by past studies.

Our systematic review identified that the Government of Ghana has recognized the critical importance of supporting smallholder farmers with access to irrigation water. This support aimed to increase agricultural productivity, enhance food security, and reduce farmers' vulnerability to the effects of climate change (Bieber et al., 2018; Naab et al., 2019; Nalumu et al., 2021). Recently, the government has made investments in irrigation infrastructure development for irrigation water access. One such investment was the development of traditional (public) irrigation systems. This initiative was carried out by the Ghanaian government in collaboration with non-governmental organizations (Atuobi-Yeboah et al., 2020; Yussif et al., 2018). However, the national government has paid little attention to its small-scale irrigation schemes as it emphasized large-scale systems (Amponsah et al., 2023; Boateng & Nyaaba, 2014; Salifu & Salifu, 2024). This finding highlights the need for government and development agencies to provide subsidies, training, and technical support to encourage smallholder farmers to privately access irrigation water with efficient systems (Bjornlund et al., 2017; Levidow et al., 2014).

In 2003, Ghana had 22 public irrigation projects that covered 8,785 hectares of developed land, of which 5,200 ha were under irrigation (Baldwin & Stwalley, 2022; Keraita & Cofie, 2014; Namara et al., 2011). These public irrigation systems significantly increased and supported agricultural productivity and ensured food security in Ghana. The government's commitment to invest in irrigation infrastructure had not only improved water access for farmers but had also provided employment opportunities and boosted the country's agricultural economy. However, maintenance of these irrigation systems became a challenge as the infrastructure aged and funding for repairs and upgrades became limited. This led to inefficiencies in water access and decreased crop yields. Eventually, many such infrastructures in the agricultural sector collapsed. Without proper maintenance, the public irrigation systems in Ghana failed and reversed the progress made in improving food security and boosting the economy. It became evident that the continuous success of these crucial irrigation projects in Ghana required significant investment and attention.

In recent years, the government of Ghana has launched a flagship program dubbed the "One-village one-dam" initiative nationwide to provide irrigation water and irrigation services to farmers (Baldwin and Stwalley, 2022; Keraita & Cofie, 2014). The program aimed to invest in the

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construction and rehabilitation of neglected irrigation infrastructure that includes dams, dugouts, canals, and reservoirs to store surface and rainwater for smallholder farming (Balana & Akudugu, 2023; Kemeze, 2020). The program was expected to have a significant impact on reliable irrigation water access for agriculture and rural development. It was also to provide farmers who are interested in the program a cost-effective and reliable source of irrigation (Kuwornu & Owusu, 2012). However, we found that the high construction cost of the irrigation facilities and funding allocation was often competitive with other sectors of the economy (Giordano & De Fraiture, 2014; Namara et al., 2011). These factors further led to insufficient investment in water storage facilities, limited access to irrigation technologies, and equipment for farmers (Table 2). Consequently, farmers tend to face unreliable and inconsistent water access for their agricultural activities (Boateng et al., 2024; Dawuni, 2024; Mantey et al., 2024). We further found that productivity and yield decreased because of the unreliable irrigation water access (Ankrah et al., 2023; Arfasa et al., 2024; Tette et al., 2024). In addition, food insecurity, decreased incomes, and poor livelihoods were experienced due to the insufficient access to irrigation water for farms (Akudugu et al., 2021; Salifu & Salifu, 2024).

We also found some interventions for access to irrigation water for farms in Ghana under the terms of the New Partnership for Africa's Development (NEPAD) and the Comprehensive Africa Agriculture Development Program (CAADP). This intervention tasked the Ghanaian government with devoting 10% of its national spending on agriculture to support irrigation water access, reduce the country's dependence on rain-fed agriculture, and increase resilience to climate change. However, this intervention did not materialize as planned. Maintenance and operational costs also led to the abandonment of several such projects. Additionally, our investigation identified budget constraints, limited funding, bureaucratic hurdles, and other factors that contributed to the abandonment of water access projects in the past. As a result, Ghana did not fully realize the expected benefits of irrigation for smallholder farming. Ghana tends to import more food, such as rice, than it exports, putting additional strain on the nation's foreign exchange reserves (Adams et al., 2024; Nyarko & Kassai, 2017).

4.2 Temperature and Rainfall Patterns

The systematic review revealed that surface water systems are particularly vulnerable to the impacts of climate change (Mensah et al., 2022) (Table 3). Climate change has increased the variability of weather patterns and altered the dynamics of moisture and heat transfer (Abungba et al., 2020). High temperatures increased evapotranspiration rates of surface water bodies and intensified water loss from both soil and plant surfaces (Boamah et al., 2024). Additionally, climate change influenced precipitation and temperature change patterns. Changes in temperature and rainfall patterns in Ghana present significant challenges to the consistent availability of irrigation water for smallholder farmers. The result showed that the rise in temperatures due to climate change negatively impacted farmers' access to reliable irrigation water (Gyimah, 2020). Drought stress during critical growth periods resulted in reduced yields and contributed to food insecurity (Kansanga et al., 2022).

The result showed that water sources are vulnerable because of the rise in temperatures and changes in precipitation patterns. Changes in the frequency, duration, and intensity of rainfall invariably affected rivers and stream flow and the resultant storage volumes of reservoirs. For example, such changes manifested themselves in the form of increased intensity of floods or occurrence of severe droughts, which affected the water sources at local and regional levels. In Ghana, drought is a dominant climate risk, which destroyed the livelihoods of smallholders and their communities. It shattered their food security and further had a significant negative effect on gross domestic product (GDP) growth. In addition, floods negatively affected infrastructure, transportation, agriculture, the flow of goods and services, access to clean water, and public health.

In regions where irrigation infrastructure is underdeveloped or nonexistent, farmers' water demand increases (Agodzo et al., 2023). Studies have shown that rising temperatures have contributed to soil moisture deficits in northern Ghana, where the dry season has become increasingly hotter and longer (Abagale & Tetteh, 2011; MacCarthy et al., 2022). This phenomenon has led to greater reliance on seasonal rainfall, making irrigation a necessity for farmers. The review found heat stress on crops and faster drying of water sources (Kyei-Mensah et al., 2019; Martey et al., 2021). Additionally, some studies emphasized the vulnerability of farmers and the need for irrigation. However, water access becomes more uncertain and limited for farmers (Amisigo et al., 2015).

Smallholder farmers in Ghana rely on rain-fed agriculture in the absence of proper irrigation infrastructure such as reservoirs, canals, and dams (Oteng-Darko, 2018). Unfortunately, rainfall has become erratic and unpredictable due to climate change (Asare-Nuamah & Botchway, 2019). The heavy reliance on rainfall made agriculture highly vulnerable to the erratic and unpredictable nature of rainfall patterns (Derbile et al., 2022). The delayed onset of rains and uneven seasonal distributions affected farms and productivity (Antwi-Agyei, 2012). Crops and farms were often destroyed due to floods when intense rains unexpectedly occurred, posing a significant threat to agricultural productivity and food security (Ani et al., 2022; Nyantakyi-Frimpong, 2023; Zakaria & Matsui, 2021). Furthermore, farmers' livelihoods were threatened in regions without irrigation access (Asitoakor et al., 2022; Derbile et al., 2022; Yiran & Stringer, 2016). Farmers became uncertain about planting and harvesting cycles, which affected farm planning and productivity (Nyamekye, 2021). This finding highlights the need for climate-resilient irrigation solutions in Ghana.

Farmers' perceptions of the risk to their farms from weather/climate variability is another issue affecting how they consider and use climate and weather information. Yaro (2013) indicated that

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the primary motivation for individual farmers was an awareness of some level of vulnerability to impacts of climate variability and the opportunity to reduce that vulnerability through appropriate use of forecast information. Crane et al. (2010) found that farmers know they cannot avoid all weather-related risks to their farm operation and thus employ management or coping strategies that ensure some yield during most years and under most adverse conditions. We also found that rainfall variability increases crop disease incidents and causes significant reductions in the fertility of soil.

4.3 Land Tenure and Inadequate/Poor Irrigation Infrastructure Development

As far as our review found, there were some interventions for developing irrigation infrastructure in Ghana to enhance agricultural productivity and revamp the regional and local economies (Acheampong et al., 2018) (Table 3). Similar to other parts of Ghana, some communities in the South Tongu District of the Volta Region benefited from the Ghana Wetland Management project. Additionally, the South Tongu District Assembly introduced catchment planning and small-scale irrigation in several local farming communities as part of the Village Infrastructure Projects (VIPs). These initiatives aimed to provide irrigation water access for farms and helped increase productivity and yields, as well as alleviate rural poverty. However, we found that land-use-related issues remained significant constraints to these projects (Koo et al., 2020). Land ownership and renting arrangements led farmers to either overexploit the land or refuse to invest in irrigation facilities (Ayelazuno, 2019).

Additionally, the prevalence of certain customary tenancies represents potential barriers to adequate land management by farmers for irrigation infrastructural development (Awunyo-Akaba et al., 2016). Farmers tend to abandon the projects and resort to rain-fed farming. Our finding indicated that the farmers left the projects due to the cost of operation, repair, and maintenance. A lack of technical and financial support from the local government in maintaining the smooth running of these facilities was identified (Anang et al., 2015; Darko et al., 2020; Kyire et al., 2023; Nakawuka et al., 2018).

Table 3: Summary of Review Results on Reliable Access to Irrigation Water in Ghana

Review topics	Focus of past studies (irrigation)	Findings	Citations
Investment in irrigation infrastructure	Government investment in irrigation infrastructure developments for years to support smallholder farmers with irrigation water access.	Many of these infrastructures collapsed due to a lack of proper maintenance, high operational costs, and a lack of or inadequate investment in irrigation.	(Adams et al., 2024; Akudugu et al., 2021; Amponsah et al., 2023; Ankrah et al., 2023; Arfasa et al., 2024; Atuobi-Yeboah et al., 2020; Balana & Akudugu, 2023; Baldwin & Stwalley, 2022; Bieber et al., 2018; Bjornlund et al., 2017; Boateng & Nyaaba, 2014; Boateng et al., 2024; Dawuni, 2024; Giordano & De Fraiture, 2014; Kemeze, 2020; Keraita & Cofie, 2014; Kuwornu & Owusu, 2012; Levidow et al., 2014; Mantey et al., 2024; Naab et al., 2019; Namara et al., 2011; Nyarko & Kassai, 2017; Salifu & Salifu, 2024; Tette et al., 2024; Yussif et al., 2018)
Temperature and rainfall patterns	Climate change related challenges for smallholder farmers	Reliance on rain-fed production without ditches, canals, and reservoirs made farmers highly vulnerable to erratic and unpredictable rainfall patterns. Crops and farms were often destroyed due to floods. Drought from high temperatures affects farmers' productivity and yield.	(Abagale & Tetteh, 2011; Abungba et al., 2020; Agodzo et al., 2023; Amisigo et al., 2015; Ani et al., 2022; Antwi-Agyei, 2012; Asare-Nuamah & Botchway, 2019; Asitoakor et al., 2022; Boamah et al., 2024; Crane et al., 2010; Derbile et al., 2022; Gyimah, 2020; Kansanga et al., 2022; Kyei-Mensah et al., 2019; MacCarthy et al., 2022; Martey et al., 2021; Mensah et al., 2022; Nyamekye, 2021; Nyantakyi-Frimpong, 2023; Oteng-Darko, 2018; Yaro, 2013; Yiran & Stringer, 2016; Zakaria & Matsui, 2021)
Land tenure and inadequate or poor irrigation infrastructure development	Land-use-related issues with regard to irrigation adoption/projects	Land ownership and renting arrangements led farmers to either overexploit the land or refuse to invest in irrigation facilities. Farmers tend to abandon the projects and resort to rain-fed farming.	(Acheampong et al., 2018; Anang et al., 2015; Awunyo-Akaba et al., 2016; Ayelazuno, 2019; Darko et al., 2020; Koo et al., 2020; Kyire et al., 2023; Nakawuka et al., 2018)

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5. CONCLUSION AND RECOMMENDATIONS

This paper investigates the reliability of irrigation water access for smallholder farmers in Ghana through a systematic review of previous studies. The study shows that Ghana has the potential for irrigation development but has failed to improve irrigation water access to farms for some reasons. For some years, rainfall contributed to improved water access, and some irrigation facilities, such as reservoirs, were successfully installed. However, poor maintenance was a major factor in the early demise of these systems. A key reason behind this failure was the lack of sustained efforts to invest in irrigation infrastructure and technology. Farmers were not fully empowered with reliable access to irrigation water to enhance productivity and food security. Even with the interventions from donors and non-governmental organizations such as the World Bank, Japan International Cooperation Agency, and Korea International Cooperation Agency, several projects that aimed to make irrigation water accessible were abandoned due to high maintenance and operational costs, among others. This highlights the need for credit support from the government.

Climate change was another impediment that slowed the rate of irrigation adoption among smallholder farmers. During the wet season, increased rainfall led to higher stream flows, indicating the need for infrastructure support for farmers to channel water for storage and prevent flood damages and losses. In line with previous studies conducted in Asian countries such as Sri Lanka and Bangladesh, erratic rainfall patterns have caused flood damage, crop losses, and led to farmers losing their investments (Eeswaran, 2018; Hossain et al., 2024; Islam et al., 2024; Weerakoon et al., 2023). Similar to past studies in Ethiopia and India, floods often washed away earth embankments and other structures that farmers constructed (Gurmu et al., 2024; Legese et al., 2020; Sahani et al., 2023). Changes in rainfall frequency and intensity influenced stream flows and storage volume of surface water sources, as shown in recent studies in Rwanda (Macharia et al., 2023; Muhumure et al., 2024), highlighting the need for investment in irrigation infrastructure. Decreased rainfall resulted in drought conditions. As a result, farmers struggled to irrigate their crops. Sometimes, unpredictable rainfall patterns made it difficult for farmers who irrigate to plan and manage water sources. A lack of flood and drought mitigation measures on farms complicated farmers' ability to effectively manage water sources. Surface water bodies often dried up because of the high temperatures, which sometimes made it difficult for farmers to access water. Rising temperatures often brought about extreme drought incidents, which affected yield and food security, as found by past studies.

To this end, we recommend that private settings invest in irrigation as a business venture. For instance, real estate companies or even government agencies could invest in land and irrigation development. They could then lease or sell the land and facilities to farmers under specific terms and a repayment system. Such facilities should have basic social amenities, including accessible roads to markets. In addition, the district assemblies, in collaboration with government agencies

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such as the Ghana Irrigation Development Agency (GIDA), should prioritize seasonal water availability and infrastructure investment. They should also focus on maintenance and local farming practices. Financial management planning institutions could be introduced with experts to advise farmers before and after adopting irrigation. Other institutions, including GIDA and MOFA, should diagnose farmers' irrigation needs. They should also encourage and empower water user associations. These institutions should generate a roadmap for a water access strategy for farmers as part of national development plans. This could include the development of multi-purpose water infrastructure along riverbanks and in hinterlands, as well as the creation, rehabilitation, and modernization of irrigation systems. Collaboration between government, organizations, and communities is essential for developing suitable irrigation facilities (such as reservoirs) to build resilience among farmers. Additionally, there is a need for GIDA, MOFA, and other relevant stakeholders to observe, identify, learn, and adopt successful stories of reliable irrigation water access from other countries. For example, in Japan, improved irrigation access has led to increased crop yields and agricultural stability.

6. STUDY LIMITATIONS

A key limitation of this systematic review on reliable irrigation water access for smallholder farmers in Ghana is the lack of region-specific, peer-reviewed studies. Few existing studies thoroughly examine the nature of irrigation reliability in the Ghanaian context. Other existing literature focuses on broader agricultural water management issues or is limited to specific regions. This makes it difficult to generalize findings across the country's diverse agro-ecological zones. Furthermore, several studies in Ghana rely on localized case studies or qualitative assessments. This constrains the ability to compare results or infer national-level conclusions. The absence of consistent criteria definitions and indicators for "reliable access" among past studies further complicates synthesis. These limitations may influence the generalizability and applicability of the review's outcomes for policy and practice throughout Ghana.

Authors' Contributions

This article involves contributions from all three authors. The lead author, T. M. K., developed the methodology and reviewed the article. He also curated the data and drafted the manuscript. B. M. and S. S. contributed to the review, editing, and proofreading of the article. All authors approved the final version of the manuscript.

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