



Farmer advisory and adoption of irrigation for climate adaptation and cocoa productivity in Ashanti, Ghana

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Farmer advisory and adoption of irrigation for climate adaptation and cocoa productivity in Ashanti, Ghana

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Abstract

The issue of climate change cannot be overemphasized, especially in the global south where many smallholder farmers are vulnerable due to their incapacity to withstand climate shocks and stressors. However, many smallholders are also actively developing strategies to cope with these challenges. In the cocoa sector of Ghana, they experience change of rainfall pattern resulting in longer dry seasons and rising temperatures that has affected the productivity of cocoa. This study aimed to assess farmer advisory services and the adoption of irrigation technology in enhancing cocoa productivity and climate adaptation in the Ashanti Region of Ghana, specifically within the Ahafo Ano Southwest District. This study provides a field-based analysis on how advisory is delivered, the challenges faced in delivery, and the potential for scaling irrigation for climate adaptation in cocoa farming. Interviews was conducted with sixteen farmer advisory service providers representing public, private, formal and informal advisory services, including five farmers. Participants stated key issues affecting the adoption of irrigation technologies, including water quality and inadequate infrastructure. Similarly, irrigating young cocoa plants was considered a desired adaptation strategy. Cocoa farmers see irrigation as helpful for better yields and coping with climate change, but few use it due to inadequate access to knowledge, polluted water, and high costs. Drip irrigation was preferred but hard to adopt without support and training. The study recommends improving interactions between farmers and extension officers, to provide affordable irrigation systems, organize training programs, and encourage partnerships between government, NGOs, and farmer groups. These efforts can improve cocoa farming, help farmers adapt to climate change, and support global goals like clean water (SDG 6), climate adaptation (SDG13) and land conservation (SDG15).

Keywords: Smallholder farmers, Technology adoption, Irrigation, Agricultural knowledge and information system (AKIS) climate smart agriculture(CSA), humid tropics agriculture.

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Abbreviations

AKIS	Agricultural knowledge and information system
ARCGIS	Aeronautical Reconnaissance Coverage Geographic Information System
AWM	Agricultural Water Management
CDD	Consecutive Dry Days
CGIAR	Consultative Group on International Agricultural Research
CSA	Climate Smart Agriculture
CWD	Consecutive Wet Days
DAES	Directorate of Agricultural Extension Services
DPSIR	Driver-Pressure-State-Impact-Response
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
GFAAS	Ghana for Agricultural Advisory Support and Services
ILSSI	Innovation Lab For Small Scale Irrigation
IWMI	International Water Management Institute
LE	Limited Enterprise
MOFA	Ministry of Food and Agriculture
MS	Moderately Suitable
NGO	Non Governmental Organisation
S	Suitable
SLF	Sustainable Livelihood Framework
SME	Small Medium Enterprise
TAFS-WCA	Transforming Agrifood Systems in West and Central Africa
VS	Very Suitable
WB	World Bank

1. Introduction

1.1 Background of the study

Agriculture is an integral part of rural livelihoods, global food security and economic stability. But climate change has become a setback that is affecting smallholder farmers in the global south, where many rural farmers rely majorly on rain-fed agriculture (Totin et al., 2018). In the Sub-Saharan Africa, the urgency of climate adaptation is particularly acute due to increasing variability in rainfall, declining soil fertility and prolonged dry seasons (Abegunde et al., 2019). The weather variations in rainfall patterns, inconsistency and increasing temperatures, including an extended dry period have negatively impacted the level of agricultural productivity. This also has necessitated the move for adaptation strategies in farm management to support and enhance yields and farmer livelihoods. Abegunde et al. (2019) argue that adaptation initiatives in Africa often fail to consider the social and institutional contexts of farming systems. This points out that there exist a mismatch between top-down technology dissemination and the actual needs and capacities of farmers. Kombat et al. (2021) highlight that while awareness of climate smart agriculture among smallholders is increasing, adoption remains uneven due to barriers such as limited financial resources, lack of access to inputs, and weak extension systems. Kombat et al. (2021) stress the relevance to have a solid collaboration among advisory service providers, farmers and researchers to bridge knowledge gaps and support technology uptake.

In Ghana's Ashanti Region, cocoa farmers face a complex interplay of climate stress, degraded water resources, limited infrastructure, and weak extension services. Although irrigation is widely promoted as a climate adaptation strategy, its adoption remains low. This raises critical concerns about the assumption that providing knowledge or technologies, such as irrigation, will automatically lead to widespread adoption and improved livelihoods (Leeuwis, 2004; Knierim et al., 2015). The role of Agricultural Knowledge and Innovation Systems (AKIS) is relevant and can drive the change needed for farmers to adapt to climate issues through improved management and technology use. AKIS refers to the network of people, organizations, and institutions that create, share, and use knowledge and ideas in farming (Leeuwis, 2004). AKIS is a way to explain the connectivity of farmers, advisors, researchers, private companies, and stakeholders to facilitate the flow of information, innovations, and support services needed for agricultural development (Knierim et al., 2015).

Among the key strategies within CSA is the use of irrigation technologies to reduce reliance on variable rainfall. Irrigation has become increasingly necessary in areas

where weather patterns are no longer predictable (Gbodji et al., 2023). This means that irrigation is a key adaptive measure that is critical to ensure maximal agricultural resilience when irrigation technologies are adopted, especially in regions where rainfall is becoming increasingly unreliable. Although irrigation is promoted as a key climate-smart agriculture (CSA) strategy, it is important to recognize that it can also have several negative environmental and social impacts if not properly managed. For example: poor irrigation practices may lead to soil salinization, waterlogging, depletion of groundwater resources, and reduced water quality due to agrochemical runoff (Gondwe et al., 2021). To maximize the benefits of irrigation as a CSA strategy while minimizing its risks, careful planning and management are needed. Strategies include promoting efficient irrigation methods such as drip irrigation, which reduces water waste and minimizes soil degradation (FAO, 2017).

One common assumption in climate adaptation discourse is that technological interventions like irrigation will straightforwardly enhance productivity and thereby reduce poverty. This linear logic is increasingly challenged by evidence showing that improved yields do not always translate to improved livelihoods (Daoud, 2010; Scoones et al., 2015). Structural constraints such as land tenure insecurity, market volatility, and environmental degradation, for example due to illegal mining complicate this equation and may undermine the benefits irrigation is meant to provide.

Ghana's economy and rural livelihoods are deeply intertwined with cocoa farming. For example, the Ashanti region in Ghana has been a major hub for cocoa production. Ghana contributes about 15-20% of global cocoa supply, making agriculture and particularly cocoa farming a cornerstone of its economy and the global chocolate industry (FAO, 2023). Initially, cocoa was farmed using traditional methods that relied heavily on natural rainfalls and manual labour. These techniques frequently resulted in low productivity due to issues around intermittent dry spells combined with poor soil fertility, diseases, and pest infestations (Wiredu et al., 2011).

FAO (2021) in the Aquasat-FAO's Global information system on Water and Agriculture, presents projections showing that rainfed cocoa production in suitable areas could decrease significantly by the 2050s and 2080s due to climate change. Specifically, cocoa production could decline to 72% of baseline levels by the 2050s, and to just 35% by the 2080s on land that is currently considered suitable. Noting that areas suitable for cocoa production may shrink to only one-third of current levels by the 2080s in Ghana under high-end climate change scenarios with yields dropping by more than 60% on currently suitable land (FAO (2021)).

Despite growing recognition of the challenges cocoa farmers face due to climate change, and increasing attention to irrigation as a climate-smart solution, there is limited research on how farmers in cocoa-producing regions of Ghana actually access and use knowledge about irrigation technologies. More knowledge is needed to understanding of the role of advisory service providers, both informal and formal that can shape farmers' attitudes, awareness, and decisions about irrigation. While some existing studies focus on broad climate-smart agriculture adoption or on technical aspects of irrigation systems, a few examine the institutional, social and knowledge-related barriers specific to cocoa irrigation in Ghana.

In response, frameworks like climate smart agriculture (CSA) have been advanced to promote adaptation strategies such as irrigation, improved varieties, and conservation practices (Tambol et al., 2025). CSA is often framed around three core goals: enhanced resilience, increased productivity and reduced greenhouse gas emissions. However, these goals are not unproblematic. Critics argue that CSA has become a buzzword that obscures unequal power relations and promotes technocratic fixes to deeply social and political problems Whaley (2022). Its implementation often favours better-resourced farmers, reinforcing existing inequalities rather than transforming them Whaley (2022).

Similarly, terms like "resilience" and "sustainability" are widely invoked in agricultural policy and research, yet they lack consistent definitions and are frequently stripped of their social and political dimensions (Scoones, 2015). For instance, describing a farming system as resilient may overlook the uneven capacities of different households to adapt, especially in the absence of institutional support, land security, or access to water (Ribot, 2010). Therefore, these concepts require contextualization and critical scrutiny rather than being used as universally positive descriptors.

This thesis critically examines the role of advisory services and AKIS actors in influencing the adoption of irrigation in cocoa farming. It interrogates not only technical knowledge gaps but also the social, institutional, and ecological dynamics shaping farmer decisions, providing an understanding of the barriers to irrigation adoption and explore the extent to which advisory services can address not just technical gaps but also institutional and environmental challenges. Similarly, AKIS are not neutral, they can as well reproduce power hierarchies or marginalize certain farmer voices for example smallholders such as women.

1.2 Aim and research questions

1.2.1 Research aim

The study investigates the adoption of irrigation technologies among cocoa farmers and explore the role of Agricultural Knowledge and Information System (AKIS) actors, evaluating practical ideas to improve climate adaptation and strengthen farmers' livelihoods in the Ashanti Region of Ghana. It seeks to assess the perceptions, experiences, and interactions of key AKIS actors, including extension agents, advisory service providers, institutions and farmers regarding irrigation as a climate adaptation strategy.

1.2.2 Research questions

To study the research problem on assessment of farmer advisory services and how irrigation adoption enhance the productivity and sustainability of cocoa and intercropped cocoa farming in the Ashanti Region, while addressing challenges such as water management, climate change, and farmers' livelihoods, the thesis will further address the following research questions in the Ashanti region:

- i. How does illegal mining activity affect cocoa farmers' access to water and their capacity to adopt irrigation technologies in the Ashanti Region?
- ii. How do cocoa farmers and advisory service providers perceive the role of irrigation to cope with climate change in the Ashanti Region of Ghana?
- iii. In what ways do formal and informal advisory networks, including extension services, private actors, and peer learning, facilitate or hinder access to irrigation knowledge and technologies?

1.2.3 Thesis layout

This thesis is broken down into seven sections, the first section includes the introduction, background of the study, research aim and research questions. The second section comprises literature reviews. The third section cover the theoretical framework and concepts. The fourth section deals with the methodology and research design including context/study area. The fifth section is presentation of findings. In the sixth section, is discussion and the seventh section, I draw conclusions and outline key findings and recommendations.

2. Literature Review

2.1 Climate Change, Agricultural Knowledge and Innovation Systems (AKIS)

Climate change poses significant challenges to cocoa farming, particularly in Ghana, the world's second-largest cocoa producer. The increasing frequency of extreme weather events, such as prolonged droughts and erratic rainfall patterns, has adversely affected cocoa yields. According to the International Water Management Institute (IWMI), "extended droughts, more intense heat, and wetter wet seasons are already affecting cocoa yield in Ghana" (IWMI, 2023). Totin et al. (2018) looks at Climate Smart Agriculture from an institutional perspective. That means it asks: what kind of systems, support, and rules do farmers need to actually use these smart farming methods? In essence, just giving a farmer new technology such as irrigation tools or better seeds is not enough because farmers also need support from government and organisations like NGOs, good policies, access to markets, training and knowledge etc. This aligns with Tambol et al., (2025), even though farmers use these smart techniques they still encounter issues like no formal educations to be able to adopt new ideas quickly.

Recent discourse emphasizes that Agricultural Knowledge and Innovation Systems (AKIS) which simply refer to the network of individuals, organizations, and institutions involved in generating, sharing, and applying knowledge and innovations in agriculture play an important role in supporting climate-smart agriculture (CSA) and adaptation strategies, particularly in smallholder farming systems focused on commercial crops like cocoa (Daum, 2025). The AKIS aims to bridge the gap between science and practice, ensuring that useful research reaches farmers and that farmer needs inform research agendas. For example, a study by (Klerkx, Aarts, & Leeuwis, 2010), explored that collaborative networks within AKIS significantly enhanced the dissemination of sustainable farming practices. Similarly, (Knierim et al., 2015) highlighted that AKIS play a role in facilitating knowledge exchange between researchers and farmers making the agricultural systems withstand challenges better. "Adaptation in agriculture involves adjustments in practices, processes, and structures to moderate potential damages or to benefit from opportunities associated with climate change. For example, introducing irrigation systems is a good that can help cocoa farmers mitigate the risks of drought and irregular rainfall by ensuring a more consistent water supply" (Howden et al., 2007). Adaptation strategies help farmers cope with reduced rainfall, soil degradation, or new pest and disease pressures by enhancing resilience and maintaining or improving agricultural productivity.

As climate smart agriculture becomes more widespread, AKIS must also address emerging knowledge gaps by fostering both hard skills (like data interpretation) and soft skills (like collaboration and critical thinking), while ensuring that power does not concentrate in the hands of tech providers alone. Therefore, strengthening AKIS is central to empowering cocoa farmers to adopt irrigation and other CSA measures. This is important because of the lack of timely access to practical knowledge, new technologies, and advisory support needed to adapt to changing climate conditions by many cocoa farmers. By improving the flow of information and collaboration between researchers, extension agents, and farmers, AKIS helps farmers make informed decisions that boost productivity, conserve water, and enhance household resilience against climate shocks that improve productivity and household resilience in the face of climate change (Daum, 2025).

Approach like Climate Smart Agriculture (CSA) can help smallholder farmers tackle climate change issues. CSA is a sustainable way of boosting and improving cocoa productivity while reducing greenhouse gases and achieve national food security and development goals (Totin et al., 2018, p2). In the context of cocoa farming, practices such as drip irrigation and rainwater harvesting have been promoted to improve on the usage of water for efficiency and adapt to changing rainfall patterns (Aryal et al., 2025). However, despite the potential of CSA, its effectiveness is often limited by systemic constraints. These include inadequate access to credit, limited land availability, weak extension services, and insufficient technical support (Tambol et al., 2025; Bazzana et al., 2025). Moreover, many smallholder farmers frequently struggle with low literacy levels and limited access to digital tools, which further impede their ability to adopt and benefit from CSA interventions (Bazzana et al., 2025). A critical issue raised in the literature is the lack of enabling environments supportive policies, market access, and institutional frameworks that are essential for scaling up CSA effectively (Totin et al., 2018; Aryal et al., 2025). What is needed is not just more of the same, but targeted reforms that address these structural constraints and genuinely empower local actors. This highlights the need for increased public and private investment in irrigation infrastructure, climate information services, and farmer training to ensure CSA reaches its full potential in vulnerable farming communities.

The Financial Times reports that record-high cocoa prices have led buyers to delay orders, attributing the price surge to "extreme weather and disease affecting cocoa harvests in key producing countries, Ivory Coast and Ghana" (Financial Times, 2024). This situation reflects the broader challenges faced by the cocoa industry due to climate induced production deficits. Moreover, Ghana has experienced unprecedented delays in cocoa deliveries, with Reuters noting a postponement of 370,000 metric tons from the 2023/24 season to the current season. This delay is linked to a significant decline in production, reaching a two-decade low, attributed

to "climate change, tree disease, and wildcat gold mining" (Reuters, 2024). These developments highlight the urgent need for adaptive strategies to mitigate the adverse effects of climate change on cocoa farming. Implementing climate-smart agricultural practices is essential because it has potential to support small farmers to withstand climate change. For this to happen, it definitely will require more than just tools to enhance the resilience of cocoa farmers and ensure the sustainability of cocoa production in Ghana.

There are specific challenges facing smallholder farmers in Ghana in trying to adopt CSA practices. A study by Oppong et al. (2021) revealed that the major problems around the CSA revolves around lack of proper training and education, insufficient governmental support, lack of climate information, financial constraints and inadequate extension services. Similarly, research by Baffour-Ata et al. (2024) highlighted that barriers like high costs of improved crop varieties, limited access to agricultural credit and inadequate government support with farm inputs. Therefore, institutional factors is instrumental to the adoption of CSA practices, because the access to extension services, land tenure security, input markets, and experience with climatic shocks influence the likelihood and extent of adoption. While existing literature provides valuable insights to this problems and opportunities that is related with CSA adoption in Ghana. There is a gap in understanding the support systems, particularly the role of advisory services and extension actors in facilitating knowledge and technology transfer that is essential for effective and sustained adoption of these irrigation technologies.

While emphasis was made from literatures on the potential of Climate Smart Agriculture and AKIS in promoting climate adaptation, few studies isolate the adoption of irrigation technologies among cocoa farmers, particularly in Ghana's Ashanti Region. Even though irrigation has been identified as a critical response to increasingly erratic rainfall and drought conditions, its uptake remains surprisingly low. Similarly, what is not well understood is how institutional coordination, knowledge flows and advisory services within AKIS affect farmers' access to, and implementation of, irrigation practices. By focusing on this area, this study will examine the specific roles of AKIS actors such as farmer networks, extension officers, and local institutions in facilitating or hindering irrigation technology uptake. Most studies focus on general advisory roles or barriers to CSA but do not drill down into how technology uptake for water management under climate stress.

2.2 The Role of Irrigation Technology

The implementation of irrigation systems not only aids in climate adaptation but also has the potential to boost cocoa productivity. The Innovation Lab for Small Scale Irrigation (ILSSI-Innovation Lab for Small Scale Irrigation,

<https://ilssi.tamu.edu>) a research and development initiative that works to improve access to and use of small-scale irrigation technologies among smallholder farmers suggests that "implementation of irrigation systems could help boost cocoa productivity by increasing yield all year round" (Lefore, Stellbauer, & Kunkle, 2023).

In the 90's irrigation became economically less interesting and there were environmental and social concerns and disappointing irrigation performance (FAO, 2020). Due to price volatility, food insecurity and declining food stocks/climate change the size of World Bank lending increased in 2008 (World Bank, 2011). Irrigation is the supply of water for crop production. Irrigation has been a significant area of public intervention to change production and livelihoods. Irrigation can change several aspects of production, for instance: it can intensify land use (more crops per year), it can stabilize and increase yield allowing for different valuable crops to be grown. In dry and seasonal climates, it allows several crops a year to be grown. (Gbodji et al., 2023) pointed that with proper irrigation, yields can increase to 800–1000 kg/ha or more, depending on complementary practices such as fertilization, pruning, and shade management. Irrigation has been identified as a key strategy within CSA that can help mitigate the effects of irregular rainfall and drought. Sahoo and Moharaj (2024) emphasize that farmers with access to irrigation are more likely to adopt broader CSA practices because irrigation stabilizes yields and improves crop resilience. Aryal et al. (2025) further support this by highlighting that irrigation is central to transforming agriculture towards a more climate-resilient system.

In seasonal climates with a dry season, irrigation can allow early planting, so that crops can make maximum use of subsequent rain or warmer weather, and also sometimes early planting allows an early harvest before adverse weather (very wet, foggy, or cold) sets in. In climates with dry periods, it ensures water is available to overcome dry spells. In cold periods or cold nights, irrigation can be used as protection against frost damage. Despite its advantages, it is still a small area of Ghana's potential irrigable land that is currently under irrigation with an estimated irrigation potential of 500,000 hectares, with only about 10,000 hectares (2%) that have been developed for irrigation purposes, due to limited infrastructure and high investment costs (FAO, 2021). Akudugu et al.,(2021) highlighted that irrigation allows for a multiple cropping seasons, thereby reducing excessive dependence on rainfall which currently is unpredictable, leading to increased agricultural productivity and improved livelihoods.

The International Water Management Institute (IWMI) emphasizes that "supplementary irrigation in the form of solar pumps and climate-smart eco-

friendly technologies are being explored" to address the impact of climate change on cocoa (IWMI, 2023). Sometimes solar pumps are not always available, which means that irrigation is not always climate smart, but on this note CSA should be understood primarily as a framework for enhancing farmers' capacity to adapt to climate risks, rather than strictly minimizing emissions. However, there are several renewable green energy sources for example wind or micro-hydro systems also can support sustainable irrigation. Irrigation can still be climate smart if powered by any green energy source that reduces greenhouse gas emissions and ensures efficient water use (Daum, 2025). Irrigation systems not only support crop production: the water supply is also very important for domestic uses, for local agro-processing and for livestock breeding (often important in irrigation systems for providing traction as well as milk, meat and leather). Often reservoirs and streams supporting irrigation are used for fishing. Irrigation supplements rainfall where it is not sufficient to reliably satisfy crop water requirement, in areas vulnerable to climatic variability or where multiple cropping requires the provision of water outside the rainy season.

Irrigation importance in Ghana can not be overemphasized, studies have shown that irrigation does not just improve yield, but it also give farmers the opportunity to be productive all year-round regardless of weather changes, thus reducing poverty and improving resilience to climate change (Sibale et al., 2025). However, the level of irrigation schemes that exists still remains low due to factors such as limited maintenance, poor infrastructure and inefficient water management systems. For instance, in the Bontanga irrigation scheme, the average overall irrigation efficiency was found to be only 31.3%, far below the expected standard of 60% (Sibale et al., 2025). It is worth noting that It is worth noting that irrigation While large-scale monitoring systems such as FAO's WaPOR and national initiatives in countries like India and the US support SDG 6.3 and 6.4 reporting, localized data on irrigation efficiency, especially at the smallholder level still remains inconsistently integrated into planning and evaluation frameworks.

Although my focus is on the Ashanti region, a quick global reflection on irrigation shows that global trends in irrigation and the success of irrigation systems in other countries can provide a broader context for why irrigation is an important consideration for addressing climate change impacts in cocoa farming. While irrigation has the potential to revolutionize agriculture by stabilizing yields, enabling year-round farming, and enhancing resilience to climate change, the evidence from Ghana shows a persistent gap between potential and practice (Djangba et al., 2024; Sibale et al., 2025). The role of irrigation by authors did not give any possible negative reflection of irrigation use, like using excess water and the implications on the environment. Even though irrigation is important for dealing

with irregular rainfall and drought, not many farmers are using it. It's also not clear how support from various groups such as farmer networks, local institutions and extension officers prevents or help farmers from using irrigation. Most research looks at general challenges to CSA but doesn't focus on how these support systems affect the use of irrigation for managing water during climate stress

The need for a deliberate consideration about the local situation and the people involved before calling it a perfect answer is important too

3. Theory and Concepts

3.1 Sustainable Livelihoods Framework in Agricultural Research

The Sustainable Livelihoods Framework (SLF) is relevant for this study to have a better understanding on how cocoa farmers make decisions about their livelihoods, and because this study uses semi structured interview (qualitative method), the SLF helps organize different types of information in a clear and connected way especially when facing challenges like climate change and decisions about whether to use irrigation technology or not. Sustainable Livelihoods Scoones (1998) framework (SLF) provides a comprehensive approach to understanding how rural households sustain their livelihoods amidst external shocks and stresses. In agricultural research, the SLF has been instrumental in examining the interplay between natural, financial, social, human, and physical assets. According to Scoones (1998), “the framework emphasizes the importance of assets in shaping livelihood strategies and outcomes” (p. 5). This framework will serve as a practical guide and an analytical tool to comprehend rural poverty and resilience.

By using the SLF, this study can look at not just if farmers adopt irrigation, but how and why they do it, and what changes it brings to their lives such as more food, better income, and less risk.

The key components of the framework include:

- i. Livelihood Assets: Human, social, natural, physical, and financial capital.
- ii. Transforming Structures and Processes: Institutions, organizations, policies, and legislation.
- iii. Vulnerability Context: Shocks, trends, and seasonality affecting livelihoods.
- iv. Livelihood Strategies: The combination of activities and choices made by households.
- v. Livelihood Outcomes: Results such as increased income, well-being, reduced vulnerability, food security, and sustainable use of natural resources.

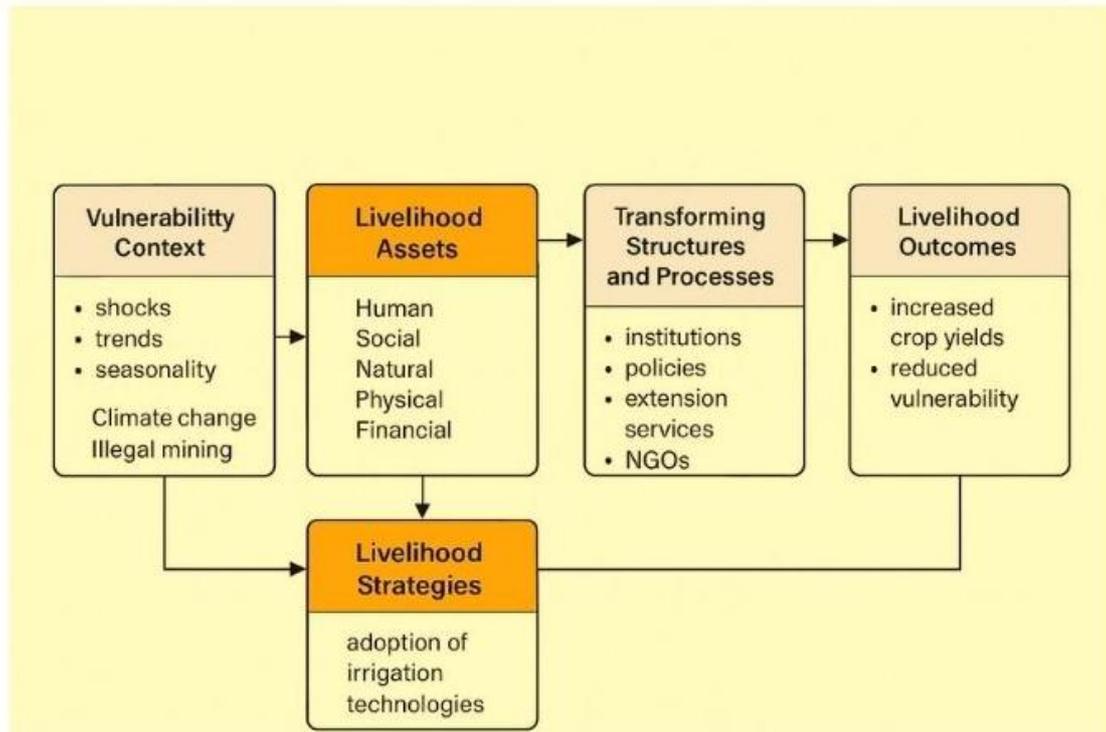


Figure 1. Sustainable Livelihoods Framework. Adapted from Sustainable Livelihoods Guidance Sheets (DFID, 1999).

The diagram figure 1, gave an illustration on how different parts of farmers’ lives affect their decision to use irrigation. It includes challenges like climate change and illegal mining (vulnerability), the resources farmers have (like money, land, and advice), and support from institutions (like extension services and government). These things influence what farmers choose to do, such as using irrigation, which then leads to better results like higher crop yields and less risk.

Scoones (1998) emphasizes that sustainability should be measured in terms of economic, institutional, social, and ecological resilience dimensions that can guide both data collection and analysis. In the context of cocoa farming, the SLF has been used to analyze how farmers adapt to climate variability and market fluctuations. Danso et al. (2020) found that “farmers who possess diverse assets are better equipped to adopt climate-smart practices and enhance their resilience to environmental changes” (p. 78). Similarly, Nyantakyi and Bezner (2015) highlighted the role of social capital in facilitating collective action and knowledge sharing among cocoa farmers. The SLF is used for analyzing irrigation adoption and to explore the reasons behind low uptake without assuming that farmers are not aware or unwilling . It also supports a move from simplistic and not complex interventions such as distributing pumps to systemic reforms that address social

equity, entitlements and institutional capacity (Leach, Mearns & Scoones, 1999). (Barrett et al., 2020) emphasized on the sociotechnical innovation bundles which integrate context specific technologies with enabling social structures and governance systems to go beyond a traditional SLF assets based. As the Expert Panel Report articulates, “no magic scientific or engineering bullets exist... innovation is as much a social process as a scientific one,” highlighting the critical interdependence of social structures, technical tools, and place-specific enablers (Barrett et al., 2020, p. 7). It reflects the consensus that “technologies need to come with financial and human/institutional capacity in order to be game changers” (Barrett et al., 2020, p. 3), reinforcing that transformation must be approached as bundled, not isolated, innovations. Critics argue that the SLF framework's linear approach oversimplifies the complexity of rural livelihoods and neglects the role of power dynamics (De Haan, 2012).

3.2 Vulnerability as a theoretical Concept

This theory signals its relevance to broader frameworks such as disaster risk, climate change and or agricultural adaptation. The SLF allows for the exploration of livelihood outcomes beyond income generation. According to Scoones (1998, 2015), sustainable livelihoods should lead to increased well-being, improved food security, reduced vulnerability. Ribot critiques that the approach to vulnerability, in his argument about the fact that vulnerability is not entered on just external events; it also comes from deeper social factors such as access to resources, social entitlement and political power. While the term vulnerability refers to the degree to which communities, individuals, or systems are susceptible to risk that may be harmful due to exposure to hazards, combined with their capacity to anticipate, recover and cope from these events Wisner et al. (2004). For Ribot and Wisner, expose to the hazard is just the last step, as vulnerability is rooted in societal structures especially poverty and marginalization. Whether you can anticipate or cope is only a small part. . In essence, vulnerability is shaped by underlying social structures not just by climatic events (Ribot, 2010). Ribot suggests that to create effective climate policies, we need to look at these root causes of vulnerability calling for a multiscale approach that considers factors at local, national, and global levels, with policies that tackle the inequalities contributing to vulnerability (Ribot, 2010).

Vulnerability in the context of smallholder cocoa farming is shaped by a range of factors that may include limited access to clean and reliable water sources, demographic challenges such as ageing farmer populations, exclusion from financial and institutional support systems and labour shortages, and unequal access to agricultural innovation and extension services. These factors can increase farmers' exposure to climate-related risks like drought, and limit their ability to

adapt through technologies such as irrigation. Understanding how these elements interact is critical for examining the conditions under which smallholders can adopt climate-resilient practices.

The livelihood strategies adopted by farmers to manage and adapt to the challenges posed by water scarcity include diversification of crops, dependence on traditional knowledge and irrigation technique, collective farmer engagement.. In climate adaptation research, vulnerability is commonly understood as a function of exposure, sensitivity, and adaptive capacity. It is multidimensional, encompassing economic, social, environmental, and institutional factors that shape people's ability to respond to change (Adger, 2006; Brooks et al., 2005).

Vulnerability economically may involve limited access to financial services, resources and markets that support investment in adaptive strategies. In terms of social aspect, it can be influenced by gender, age, education, and access to social networks or community support. Furthermore, environmental factors such as land degradation, ecological instability or water scarcity contribute to heightened risk. Institutionally, weak governance, inadequate extension services, or exclusion from decision-making processes can constrain the capacity to adapt. Understanding vulnerability through this multi-dimensional lens provides a foundation for analyzing how various forms of inequality and systemic disadvantage interact to influence adaptive behavior. This framework will guide the analysis of how individuals and communities engage with climate adaptation strategies, including the uptake of technologies such as irrigation.

Vulnerability in cocoa farming is multilayered:

- Economic vulnerability relates to high irrigation costs and lack of subsidies or credit.
- Social vulnerability includes reliance on informal knowledge systems and uneven access to innovation.
- Environmental vulnerability stems from deforestation and mining, which degrade water quality.
- Institutional vulnerability is evident in overburdened extension services.

Recognizing these dimensions is critical. As Ribot and others argue, adaptation cannot be truly effective unless it also addresses the root causes of vulnerability, social inequality, institutional failure, and political marginalization. While the Sustainable Livelihoods Framework (SLF) is used to understand asset-based livelihood strategies, the vulnerability approach complements this by asking: who is exposed, why, and how do power relations and institutional failures create or reinforce this exposure? Vulnerability helps to unpack the reasons behind uneven adaptation outcomes across farmer groups, making it a valuable lens for this study.

For irrigation to be a viable adaptation strategy, it must be supported by interventions that reduce these structural vulnerabilities, such as subsidized infrastructure, community-based water management systems, and improved extension support.

4. Methodology

The methodology used in outlining the research design to assess farmer advisory services for irrigation technology adoption and climate adaptation for cocoa crops in Ghana's Ashanti Region employed a qualitative approach with the use of semi-structured interviews as the primary data collection method. This approach aligns with the ethnographic principles described by Hammersley and Atkinson (2007) understanding the perspectives of the people being studied.

4.1 Research Design and Approach

This study applied qualitative research methods to explore the lived experiences and perceptions of advisory service providers working with irrigation technology for cocoa in the Ashanti Region. This approach was chosen because it is particularly well-suited to exploring complex social phenomena like irrigation adoption where understanding the how and why behind people's actions, motivations, and constraints is more important than measuring variables statistically (Maxwell, 2012). This allowed for a deeper understanding of the role played by advisory services in promoting irrigation technologies and challenges faced by cocoa farmers while adapting to the climate challenges. Using methods such as interviews, the study was able to capture detailed, personal insights into how advisory services influence the adoption of irrigation, the kinds of support they offer, and the everyday challenges they and cocoa farmers face in responding to climate change. It helped to uncover the meanings that individuals or groups ascribe to an issue (Creswell & Creswell, 2018:41). This study relied on qualitative method through semi-structured interviews to provide a balance between guided discussions and open-ended responses, enabling participants to share their insights while allowing flexibility in the interview process. This method ensures that the research remains focused on the study's key themes while also capturing new and unexpected perspectives (Creswell & Creswell, 2018:257). The choice of a qualitative research method for this study is because it enables for a better comprehension of not just what is happening, but also the how and why. This approach further reveals the social, cultural, and institutional factors that shape the use of irrigation technology, which are essential for designing more effective and farmer-friendly advisory services that would guide subsequent data collection and analysis.

4.2 Target Population and Sampling

The target population includes advisory service providers who work with cocoa farmers in the Ashanti region of Ghana. Onumah et al. (2021) emphasize the benefit of having diversity in terms of stakeholders involvement and how that it brings

innovation, this includes farmers, extension agents, researchers, public and private sector, to foster collaborative problem-solving and knowledge exchange in the cocoa sector. All the farmers interviewed were over 50 years old, reflecting the ageing nature of the cocoa farming population in the study area. This demographic characteristic is relevant to understanding both their experiences with climate stress and their engagement with adaptation strategies such as irrigation. The advisory respondents were drawn from a mix of public extension officers, private agribusiness consultants, and irrigation service providers. Among them I have categorized into the following groups:

- Public advisors were typically government extension officers under MOFA.
- Private advisors worked for companies involved in irrigation system design or installation (e.g., drip irrigation suppliers).
- Some private firms also engaged in selling agro-inputs or cocoa buying, which means they had commercial interest in both supporting and sourcing from farmers.(COCOBOARD)
- Research Institute (IWMI/CGIAR)
- Farmers.

All respondents were male. This reflects the gender dynamics within the advisory services and cocoa sector in the Ashanti Region, where most formal advisory and technical roles are still male-dominated. Female advisors were limited and unavailable during the data collection period. The study focused on the Ahafo Ano South District cocoa-growing areas in the Ashanti Region, which are known for their extensive cocoa farms and varying farming practices (Adusei et al., 2023). It was selected due to its strategic location in a cocoa-producing zone and its known challenges with water access, partially due to the impacts of illegal mining. This village offers lessons for understanding how cocoa farmers in marginalized rural communities adapt (or struggle to adapt) to climate risks through irrigation.

The participants were identified through multiple channels, including recommendations from agricultural extension services, professional networks (International Water management Institute), and referrals from farmers and industry stakeholders. The farmers interviewed for this study were predominantly smallholder cocoa farmers, typically managing between 2 to 5+ acres of land. Majority of the farmers were resource poor, and relied on family labour with limited external inputs. The primary crop is cocoa, and a couple of these farmers are also into intercropping with food such as plantain, cassava, vegetables and maize, mainly for household consumption and local markets. This reflects a mixed-farming system that helps manage risk and supports food security. The inclusion of representatives of these farmers in the study was essential to understand how advisory services and irrigation innovations are perceived and adopted in real-world, resource-limited farming conditions.

The selection process involved reaching out to advisory organizations, attending agricultural workshops.

The criteria for participant selection included:

- Direct involvement in advisory services or irrigation technology for cocoa farming
- Experience in the Ashanti Region's cocoa sector
- Willingness to participate and provide in-depth insights
- Availability for interviews within the study period.

A minimum of four and a maximum of five interviewees were selected from each category, except for the government institution, which had two representatives. This resulted in a total of 21 participants. The sample size ensured representation across all stakeholder groups while considering practical constraints such as time and resource availability. This selection process allowed for a comprehensive exploration of the challenges and opportunities related to irrigation adoption in cocoa farming

4.3 Material and Methods for field work

Data was collected through semi-structured interviews, which allowed for flexibility in exploring participants' views giving them the chance to talk freely while I tried to maintain the focus on the research objectives. The interview captured aspects of the context and was done face-to-face, with each session lasting no more than one hour with the help of an assistant. I was able to gain the trust of the cocoa farmers interviewed through an interpreter (assistant) who supported with translations of my interview questions. I ensured that informed consent was obtained before conducting the interviews (refer to annex for the full list of guiding questions). Among the five farmers interviewed, most belonged to the Akan ethnic group, specifically the Asante subgroup, which dominates the Ashanti Region. Farmers practiced mixed cropping systems with cocoa as the primary cash crop, supported by plantain, cassava, and maize for household consumption or local sales. Cocoa was consistently reported as the main source of income and long-term livelihood investment, while other crops helped with short-term food security and income smoothing.

An assistant played a crucial role in translating the interviews from Twi (local dialect) to English, particularly with cocoa farmers who don't speak English. This assistant served as both an interpreter and a cultural mediator, to support and to build trust with farmer interviewees and ensured that questions were accurately conveyed at the location of the study and enhanced the communication process, eliminating misunderstandings and served as an encouragement for more open responses from interviewees. However, there are chances that the involvement of

an interpreter may have influenced participants answers due to small differences in translation.

Efforts were made to minimize bias by maintaining a neutral and open-ended questioning approach in line with qualitative research principles, I ensured and reflected my positionality as an external person who represents an educated researcher with academic training. Therefore, my formal education and affiliation with a university likely influenced both how participants responded to me and how I interpreted their words, shaped by my identity and background. As scholars such as England (1994) and Rose (1997) argue, that positionality is central to fieldwork due to the fact that it shapes the knowledge that is produced. While reflexivity on the otherhand, involves thorough examination of how that the researcher's own assumptions, identity and presence affect the research process, is therefore essential (Finlay, 2002; Pillow, 2003). So, instead of trying to remove all forms of bias, I embraced reflexivity as my tool and acknowledged the existence of limitations of the data collected. This is to help me to maintain a transparent research procedure and supports for a more honest interpretation of my findings. By recognizing that knowledge is co-produced between researcher and participant, this study aims to remain sensitive to context, power relations, and the lived realities of those involved.

Each participant was provided with detailed information about the purpose of the research, the methods of data collection, and how their personal information would be used and protected. Participants were informed that their participation was voluntary, and they could withdraw at any time without any consequences. Written consent was obtained from each participant, and they were given the opportunity to ask questions and clarify any concerns. All data collected was anonymized to ensure confidentiality and used solely for the purpose of this research.

It is recognised that information and technology is shared by multiple actors in the agricultural knowledge and innovation system (AKIS) from public and private sectors, and formal and informal channels of sharing.

The following groups were interviewed:

The table below presents the categories of actors who participated in interviews conducted during the field study period in October and November 2024. The respondents were drawn from various sectors involved in agricultural input supply, policy, and farming. Actors are categorized as follows: LE refers to Large Enterprises, SME to Small and Medium-sized Enterprises, and Public includes both government agencies and public service providers.

Table 1. List of respondents interviewed during field study (October–November 2024)

Interview Code	Affiliation / Description	Actor Type
Public A	Cocoa Board(prices, promoting research, ensuring quality control, and managing the marketing and export of cocoa to enhance farmer welfare and national revenue)	Government Institution
Public B	MOFA Officer 1 (provides agricultural extension services to farmers)	Ministry of Food and Agriculture
Public C	MOFA Officer 2 (provides agricultural extension services to farmers)	Ministry of Food and Agriculture
Public D	Extension Officer 1	Public Extension
Public E	Extension Officer 2	Public Extension
Public F	Extension Officer 3	Public Extension
Public G	Extension Officer 4	Public Extension
Public H	Extension Officer 5	Public Extension
Private A	Deng Limited (designs, installs, and maintains solar power, water-pumping, and power-generation systems)	Private Irrigation Equipment
Private B	Deng Limited (designs, installs, and maintains solar power, water-pumping, and power-generation systems)	Private Irrigation Equipment
Private C	Deng Limited(designs, installs, and maintains solar power, water-pumping, and power-generation systems)	Private Irrigation Equipment

Private D	Dizengoff (provides integrated solutions, such as seeds, fertilizers, greenhouse and irrigation systems, as well as agricultural hardware, energy)	Private Agribusiness
Private E	Dizengoff (provides integrated solutions, such as seeds, fertilizers, greenhouse and irrigation systems, as well as agricultural hardware, energy)	Private Agribusiness
Private F	Tech-2 Resources Ltd(borehole drilling, water system design and installation, and irrigation infrastructure solutions)	Private Irrigation Services
Private G	Tech-2 Resources Ltd (borehole drilling, water system design and installation, and irrigation infrastructure solutions)	Private Irrigation Services
Private H	Tech-2 Resources Ltd (borehole drilling, water system design and installation, and irrigation infrastructure solutions)	Private Irrigation Services
Farmer 1	Smallholder Farmer	Mixed Cocoa Farm
Farmer 2	Smallholder Farmer	Polluted Water Source
Farmer 3	Smallholder Farmer	Using Intercropping
Farmer 4	Smallholder Farmer	Interested in Irrigation
Farmer 5	Smallholder Farmer	Manual Watering

Participants	Type of actor	Number of interviews (OCT/NOV 2024)
Deng Limited	LE(Large Enterprise)	3

Dizengoff	LE(Large Enterprise)	2
Tech-2 Resources Limited	LE(Large Enterprise)	3
Farmers	SME(Small & Medium-sized Enterprises)	5
Cocoa Board	Government Institution	1
Ministry of Food and Agricultural (MOFA)	Public	2
Extension officers	Public	5

This classification helps understand the diversity of perspectives gathered from key stakeholders in the agricultural sector, including private companies, farmers, and public agencies.

Interviews were undertaken in physical meetings and by telephone using English language and Akan (fante/twi) to communicate while there was an interpreter to translate during some selected interview sessions especially with farmers. The selection of interviewees was done by so called ‘snow ball’ method and by reaching out in actor networks of the IWMI CGIAR Research Initiative on West and Central African Food Systems Transformation (TAFS-WCA). This network played a crucial role by connecting me with key stakeholders such as researchers from the organisation who have done similar work, policymakers (COCOABOD), Farmer advisory service providers and farmers who were actively involved in agricultural and food system transformations. Through these connections, I was able to gain access to a diverse range of perspectives and ensure the interviews covered different aspects of the food systems in the region.

4.4 Overview of the Ashanti Region

The Ashanti Region is centrally located in Ghana, the western part of Africa lying between longitudes 0.15°W and 2.25°W and latitudes 5.50°N and 7.46°N. The Ashanti region shares boundaries with the Bono, Bono East, Ahafo, Eastern, Central, and Western Regions (Ghana Statistical Service, 2021). It covers 24,389 km², making it the third-largest region in Ghana (Ghana Districts, 2023). The capital which is Kumasi, recognized as the largest city in the region, serves as its administrative and cultural hub (Ghana Statistical Service, 2021). In terms of the population according to the 2021 census in Ghana, the region has a population of 5,440,463, making it the most populated region in Ghana. The population density is approximately 220 people per km² (Ghana Statistical Service, 2021).

The population is concentrated in urban areas, with Kumasi accounting for 36.1% of the regional population. About 47% of the population resides in rural areas (Ghana Statistical Service, 2021). Males make up 49.3% (2,679,914) and females 50.7% (2,760,549) of the population (Ghana Statistical Service, 2021). The region has a youthful population, with 34.5% aged 0-14 years, 61.4% aged 15-64 years, and 4.1% aged 65+ years (Ghana Statistical Service, 2021). The Akan ethnic group dominates, constituting 94.2% of the population. Other groups include the Ga-Dangme, Ewe, and Mole-Dagbani (Ghana Statistical Service, 2021). Literacy rates vary, with urban areas like Kumasi having higher literacy (73.7%) compared to rural districts like Ejura Sekyedumase (64.7% illiteracy) (Ghana Statistical Service, 2021). About 706,888 people (43.8% of the economically active population) are engaged in agriculture (farming, forestry, fishing, or hunting) (GSS, 2010). while 65% of the region's population depends on agriculture (MoFA, 2016).

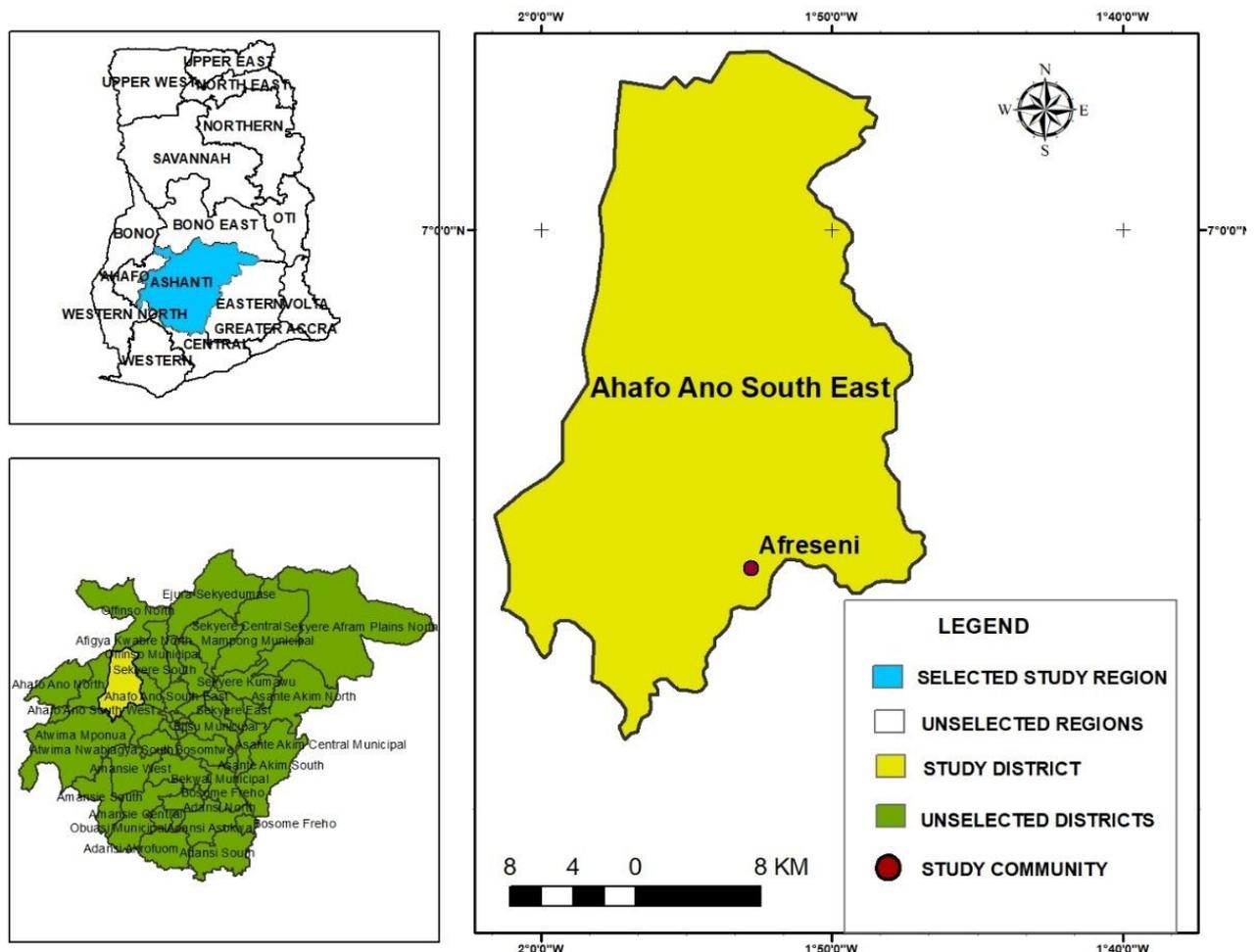


Figure 2. Map of the Ashanti Region of Ghana. Source: Author's own map generated using ArcGIS (2025), based on administrative boundary data from the Ghana Statistical Service and satellite imagery from Google Earth.

The Ashanti Region has a tropical savanna climate with two rainy seasons (Ghana Meteorological Agency, 2023).

- Major Rainy Season: March to July, peaking in May.
- Minor Rainy Season: August to November.
- Dry Season: December to February, characterized by hot and dusty conditions.

The annual rainfall ranges from 1,270 mm to 1,850 mm, with higher rainfall in the southern parts (Ghana Meteorological Agency, 2023). The average daily temperature is around 27°C, with minor variations throughout the year (Ghana Meteorological Agency, 2023). Cocoa is a major cash crop in the Ashanti Region, contributing significantly to Ghana's economy. The region is one of the leading cocoa-producing areas in the country (COCOBOARD, 2023). Although erratic rainfall and rising temperatures have reduced cocoa productivity. Farmers are adapting by diversifying crops, planting hybrid varieties, and adjusting planting schedules (Antwi-Agyei et al., 2021). Many cocoa farmers are over 50 years old, and a significant portion of cocoa farms with the average farm sizes ranging between 2 to 3 hectares are over 30 years old, leading to declining yields (COCOBOARD, 2023).

5. Presentation of findings

In this section I discuss the findings from the interviews conducted in the Ahafo Ano South District, Ashanti Region that includes the five cocoa farmers and sixteen other advisory service providers (extension officers, private companies, Government Institutions).

This analysis is structured around the following themes that emerged from the data:

1. Climate Impacts and the Role of Irrigation..
2. Perceptions and Use of Irrigation Technologies.
3. Barriers to Irrigation Adoption.
4. Access to Advisory Services

Illustrative quotes and notable anomalies are included. Findings are also linked to the Sustainable Livelihoods Framework(SLF), considering how different forms of capital (social, human, physical, financial and natural) interact with irrigation adoption and advisory services.

5.1 Climate Impacts and the Role of Irrigation

Some of the advisory services for irrigation provided advice to cope with water shortages, carried out training programs including how to use solar pumps, and operational maintenance, education for farmers adopting irrigation systems and its importance.

Farmer advisory, COCOABOARD noted that cocoa yields on rainfed farms was declining due to variable rainfall, with young cocoa plants particularly affected. Irrigated farms demonstrated better yields, underlining the importance of irrigation in addressing the yield-water gap. While only one cocoa farm in the sample had an irrigation system, revealing better yields compared to non irrigated farms, this highlighted great potential of irrigation in bridging yield water gap.

“So you cannot put a sprinkler system in a cocoa farm. You cannot put your center pivot in a cocoa farm. Or the best you can do for cocoa farm is drip irrigation..., once the drip system is there, what the farmer needs to do is to have to maintain it. Manage it.” (Private B - irrigation technology provider)

Here, the advisory service providers emphasized the importance of training programs and technical support to enhance farmer capacity for adopting irrigation. Only one farmer in the study had implemented drip irrigation for cocoa, suggesting the benefits are still anecdotal rather than widely demonstrated. More longitudinal

data would help validate these early successes. Further interviews with more irrigated farms are needed to draw broader conclusions. The impacts of supplemental irrigation on cocoa production in Ghana as stated by one of the interviewed advisory provider from the (private) that

“..the need for sustainable irrigation strategies to balance cocoa productivity with water resource preservation”. (Private C - irrigation technology provider)

Expanding affordable irrigation infrastructure and addressing water pollution in these areas’ points to the urgency for intervention, this was emphasised by an irrigation technology expert interviewed. From the examples of successful irrigation adoption in other regions and within the Ashanti and Ahafo suggest the potential for increased productivity if scaled across the Ashanti Region as one of the respondent an advisory service provider. All interviewed participants was in agreement about the fact that irrigation can enhance cocoa productivity as a better option for climate adaptation, because it can ensure consistent water supply during the dry seasons or when there is insufficient rainfall.

5.2 Barriers to Irrigation Adoption

The adoption of new agricultural technologies and practices is central to improving productivity, sustainability, and resilience, especially in the face of climate change. However, adoption is a complex process influenced by a variety of factors that can either facilitate or hinder the uptake of these innovations. Illegal mining activities was a major barrier because of polluted water sources on the rise. This concern was reiterated by advisory service providers and extension officials from both private and public institutions, emphasized the difficulty encountered in promoting irrigation when clean water access is unreliable. Therefore, the impact of "Galamsey" (i.e informal often smallscale mining) goes beyond environment and health, putting cocoa farmers in a difficult position to try new ideas or sometimes sell there farms, especially in cocoa-growing areas. 1 service provider noted,

"We can organize training for farmers on irrigation, but if their streams are contaminated, there's no point." (Public D - irrigation technology provider)

On the other hand, extension officers cited human resource shortages and mobility issues:

"a ration of about one extension officer to five hundred farmer is difficult for us to reach out to so many farmers" (Public E - extension officer)

An important point mentioned by another advisory service as it affects the installation of irrigation technology was the locations of this farm lands that requires irrigation.

“Some of the cocoa farms are usually located kilometers away from water source making it difficult to access and more expensive” (Private E - irrigation technology provider)

More resources will be involved for example it will require more pipes for streams located farther and these shared concerns has an implication that can undermine the relevance of irrigation technology. This infrastructure development for access to water may be far beyond farmer individuals.

Despite the advantages of irrigation technology, two farmers reported using sprinkler systems for their vegetable crops but not for cocoa. They attributed this to affordability challenges, lack of government support, and limited access to appropriate irrigation technologies for cocoa farming. While two farmers expressed interest in adopting irrigation if they get the support from government or any other government agency will go a long way with the potential to improve the cocoa productivity, especially in mixed cropping systems. Although some farmers have little knowledge about climate, they mentioned that noticeable weather changes, including irregular rainfall and frequency of droughts also have affected their level of productivity. Especially establishment and younger cocoa plants were particularly vulnerable to drought, causing uneven growth and production. One farmer described it as a

"survival of the fittest" situation. (Farmer 5 - farmer respondent)

Streams and other water sources were drying up more frequently, exacerbating water access issues. Here, this farmers tried to express their strong interest about adopting irrigation, but felt left out and unsupported. There was an emphasis by an irrigation service provider that there is need for government and NGO support to address these issues of financial constraint and water quality.

“If the government can help us get these systems, we are ready. It can help our cocoa grow better,” (Farmer 4 - farmer respondent).

Another major issue raised was the illegal mining (Galamsey), which was said to pollute water sources and reduce their suitability for irrigation:

"The water is not clean anymore. We can't use it for farming because it is dangerous." (Public H - extension officer statement)



Figure 3. Degraded farmland

Degraded Cocoa Farmland Due to Illegal Mining in the Ashanti Region, Ghana (Photo by Patrick Ayeni 17th October 2024).

The figure 3 above, was taken during my field trip to the Ashanti Region, showing affected area caused by illegal small-scale mining activities, commonly known as galamsey. This pollution adds a layer of environmental vulnerability that complicates irrigation development.

"The lack of water quality due to pollution is a global challenge that needs urgent attention." (Private F - irrigation technology expert)

"Galamsey activities have destroyed our water reservoirs." (Farmer 2 - farmer actor statement).

These statements above show how serious water pollution has become for farming in the area. The irrigation expert highlights that poor water quality is not just a local problem but a global one that needs quick action. The farmer's comment brings it closer to home, showing how illegal mining (galamsey) has directly damaged the water sources they depend on. Together, these views reflect how environmental damage is making it harder for farmers to use irrigation and improve their cocoa production.

5.3 Perceptions and Use of Irrigation Technologies

The interview data showed advisory providers and farmers' perceptions of irrigation technologies was shaped by their experiences, the information available to them, and the level of support they receive. The advisory service providers and extension

officers consistently described the current rainfed cocoa production system as increasingly unreliable due to erratic rainfall and prolonged dry periods. Some emphasized that the yield-water gap and the difference in productivity between rainfed and irrigated farms was becoming more visible in the region.

“The cocoa yield is much lower now, especially without irrigation. The young cocoa trees don’t survive during the dry spells.” (Public G - extension officer)

Some farmers said they use irrigation on vegetables like tomatoes, peppers, and okra. They explained that vegetables grow faster, can be sold quickly, and bring more money in a short time. In contrast, cocoa takes longer to mature and needs more investment before any return. This makes them less willing to spend money on irrigation for cocoa. When asked about maize and other food crops, farmers said maize is usually grown during the rainy season and they don’t see the need to irrigate it. Others intercropped maize or cassava with cocoa, but said irrigation for cocoa wouldn’t help much with the other crops. Regarding livestock, farmers said animals like goats and chickens are mostly managed through free grazing or small-scale feeding. They don’t require the same level of water management or investment as crops, so irrigation for livestock was not considered necessary

“Farmers harvesting under rainfed conditions often get very few bags, but with irrigation, some are now getting almost double.” (Public F - Advisory provider)

COCOBOARD and other institutional actors also acknowledged that climate variability has made the yield gap more serious than in previous years, with one expert noting that

“without supplemental irrigation, “even improved cocoa seedlings are not performing well.” (Public A - Cocoboard respondent)

“We normally access this from farmers’ feedback. They harvest fewer bags under rainfed, but irrigation gives more. The gap is real.” (Public A - Cocoboard respondent)

These institutional reflections confirm that the yield-water gap is not just anecdotal but observed widely across multiple actors in the advisory landscape. However, while recognition is high, coordinated efforts to close this gap through irrigation scale-up are still lacking. On the otherhand, an increased cocoa yields and resilience against climate variability is a way that farmers recognize that irrigation has potential benefits.

“I use drip irrigation because it saves water and feeds the roots directly.” (Farmer 5 - farmer actor)

Also, the lack of visible success stories in their communities made it harder to trust new technologies as there is no much awareness except for one farmers success story which happened to be a part of a pilot survey on the relevance of irrigation technology for cocoa productivity. Other farmers used irrigation for vegetables but not cocoa, citing high costs, a lack of training, and doubts about its practicality for cocoa specifically. For some, trying new technology felt futile without visible success in their communities.

“We don’t have the equipment or the money to try irrigation for cocoa.” (Farmer 1- farmer actor)

Perceptions have an influence whether or not farmers use and adopt irrigation, whether they are able to use it efficiently and how they use it. Two farmers talked about the poor infrastructure as a major problem aside the financial limitation. Bad roads and a lack of proper irrigation systems has always been a barrier, so trying new technology to improve their farm is futile making it hard to be more productive. Other problem like water they have access to is not clean or safe enough for farming.

A few advisory service providers highlighted both the benefits and the challenges of adopting irrigation for cocoa farming, especially in relation to cost and farmer knowledge.

“We advise farmers to use drip and sprinkler irrigation because they save water and help during dry seasons. But most farmers can’t afford them or don’t know how to use them well. So, we also teach them how much water their crops need, the best time to water, and how to check if their land is suitable.” (Public F - Advisory service provider)

Advisory service providers have always emphasized on drip and sprinkler irrigation systems to be more suitable for cocoa production, pointing out their efficiency in managing drought and optimum use of water, but pointing out that adoption remains low due to financial and technical barriers. They also provide technical advise to farmers for guidance that is meant to help farmers use water more effectively and improve crop productivity..

“Drip irrigation has shown success in pilot projects and can significantly boost cocoa yields.” (Public A - Cocoaboard)

Another respondents on the relevance of irrigation:

"Irrigation can help increase productivity, but we need resources and support to make it possible." (Farmer 3 - Farmer respondent)

There was an emphasis by an irrigation service provider that there is need for government and NGO support to address these issues of financial constraint, water quality. While it was also gathered that drip irrigation emerged as the preferred technology as mentioned by both farmers and irrigation technology provider who are engaged in the technology installation and maintenance, with several advisory provider advocating for water testing and quality analysis to ensure effective irrigation. Both farmers and advisory service providers acknowledged the relevance of drip irrigation technology, like the private companies on service provision for irrigation technology highlighted the critical role of irrigation in managing drought and excess water risks.

While farmers are aware of the benefits of irrigation, addressing deeper challenges like trust, poverty, and unequal access to resources becomes important without addressing these root problems, adoption will remain low, and cocoa productivity gains from irrigation will be limited.

5.4 Access to Advisory Services

My findings from the interviews conducted showed that farmers typically rely on a mix of advisory services, which may include formal channels such as extension services, government programs, or NGOs, as well as informal sources like peer networks or personal experience. This reliance often time are common in low-resource settings and this can be a limitation in term of uptake for more innovative or sustainable practices, especially when such practices are perceived as unproven or outside the farmers' traditional knowledge. A few farmers also emphasized self-reliance, learning from personal experience. An example of Farmer-to-farmer interaction was provided as Farmers draw on the experiences of their peers to improve their practices for example:

"Sometimes I ask my neighbor what he is doing when his cocoa looks better. We learn from each" (Farmer 2 - farmer respondent)

Another farmer pointed out challenges faced in terms of communication and minimal interaction with irrigation service providers,

“If only the government or any agency can help us with irrigation education and facilities, productivity will improve”. (Farmer 1 - farmer respondent)

On the other hand, extension officers cited human resource shortages and mobility issues:

“Sometimes we do not have transportation. Some of us have to use our own means to get to farms.” (Public F - extension officer).

This pointed out the lack of adequate support and knowledge transfer, their perception is shaped by operational limitations because of their incapacity. Poor road networks and lack of mobility for extension staff, revealing structural weaknesses in the advisory ecosystem.

However, a high farmer-to-extension officer ratio (1:500) according to one of the extension workers during the interview, making personalized support challenging. Their role in providing training, raising awareness, and offering technical advice becomes difficult due to limited staffing for personalized support.

The issue of mobility also posed a big problem for extension officers affecting their operations to support farmers. Many officers lack mobility to make a regular visit to farms that may require supervision and support to the farmers. Sometimes they spend less time while going to the field because to have to visit other farmers. The road conditions was not favourable due to its bad condition. This issues are not just a small issue, it shows a bigger problem with how extension services are planned and supported. A lack of good transport system can disrupt even a skilled officer who cannot reach farmers in need, making it hard to teach new practices on irrigation, which often need follow-up and hands-on support. This means that mobility is not just a technical issue. It is also about poor planning, low budgets, and weak support from institutions.

“There are too many farmers for us to follow up with regularly.” (Public D - Extension officer).

This highlights how overstretched resources hinder consistent farmer engagement. Fixing this means not just giving more motorbikes, but also making sure there is money, maintenance, and good systems to help officers do their jobs properly.

All the farmers interviewed were over 50 years old. Many said that young people in the village are no longer interested in farming. Instead, they go to nearby mining

sites to work, where they can earn money quickly. This has led to a shortage of farm labour, especially for physically demanding tasks like clearing land or digging trenches for irrigation pipes. Older farmers said it is difficult to manage cocoa farms on their own without help. Because of their age and limited strength, they are not willing to invest in something new like irrigation that requires long-term effort and maintenance.

Some said that if the government or NGOs helped with the setup and training, they might be willing to try. But without support, they prefer to continue with rainfed farming, even if it brings lower yields. The gaps that exist due to poor infrastructure facilities, limited reach of extension officers, and lack of proper planning all makes it difficult to set up innovations like irrigation. This lack of reliable support raises an important question: how do farmers perceive and use irrigation technologies when they are not adequately trained or supported? The next section explores how these limitations affect their understanding, acceptance, and use of irrigation systems.

Table 2. Key findings:

Theme	Key Findings
Access to Advice	Mostly informal or limited due to staff shortages
Irrigation Knowledge & Use	Interest is high; adoption low due to cost and access issues
Barriers	Financial, technical, environmental (e.g., Galamsey pollution)
Climate Challenges	Unpredictable rainfall and drought hurt yields, especially young cocoa plants

6. Discussion

This study set out to understand how extension and advisory institutions perceive the yield-water gap in cocoa production, and what role irrigation technology could play in helping cocoa farmers adapt to climate change.

6.1 Climate Impacts and the Role of Irrigation

From the results presented in this research, cocoa farmers in Ghana are feeling the impact of climate change. Low rainfall that is unpredictable, dry seasons are getting longer. Some farmers who depend solely on rainfall are facing lower yields and their crop stress. During the interviews, two farmers said they only rely on rainwater because they have no access to irrigation systems or extra water sources. This shows that rainfall alone is no longer enough for successful cocoa farming. This supports both the SLF regarding climate shocks and the vulnerability context, on the other hand AKIS emphasis about the importance of interconnected systems in ensuring that technological solutions like irrigation are effectively integrated into farmer practices. Farmers and advisory workers agree that irrigation could help reduce crop loss. By using irrigation, farmers can give their cocoa trees water during dry periods. This helps the trees stay healthy and continue producing.

Irrigation was viewed as an important way to withstand climate stress. Without it, farmers considered themselves left waiting for rain and risking their harvests. This makes cocoa farming more stressful and less productive. The study also showed that climate change is not just about weather. It is also about how farmers can respond to it. Having systems like irrigation technology, can help them adapt better. But in situations where they lack tools and support, they are stuck. Irrigation can be part of the solution. But it is not being used widely yet. It is not because farmers do not have interest. The reason was that they have a system currently that is not working well. Irrigation needs to be made more available so that more cocoa farmers can benefit from it. Extension officers themselves lack mobility and capacity shows that the problem is systemic, not just individual.

As the climate keeps changing, cocoa farming must also change. Irrigation can be way forward. It can help make cocoa farming more stable, even when the weather is not stable and unpredictable. But for this to happen, there must be better support for farmers.

A shift away from top-down approach may not be ideal, and should not be a one-size-fits-all solutions. Instead of advisory services seeking for more fund for irrigation support, the need to have a design for rural realities, and the

environmental threats to cocoa farms must be taken seriously. Therefore, it is important to fix these foundational problems before introducing new technology otherwise it will continue to bring limited results. One approach is to focus on peer-to-peer learning, where farmers can share knowledge and advice with each other, either through local groups or online platforms. Using technology, like mobile apps or SMS services, can help farmers access advice remotely, even when travel is difficult. Public-private partnerships can also help by making technology more affordable for farmers. Additionally, integrating local knowledge into advisory services and training farmers to use digital tools independently can make the support more relevant and sustainable. By combining these approaches, advisory services can become more accessible and effective without relying solely on more funding.

6.2 Barriers to Irrigation Adoption

Even though farmers were interested in using irrigation, they still had so many limitations that hinder them. One would be that they do not have access to irrigation technology. Sometimes these technology were considered expensive also, and most farmers could not afford them. It was also gathered that many water sources were polluted and not suitable for irrigating cocoa. This was mostly caused by the activities of illegal mining. Streams and rivers that used to be clean were now dirty water infected by chemicals making it unsafe, especially for food crops like cocoa. Furthermore, the roads network in cocoa areas were very bad making it hard for access while trying to install irrigation technology. Similarly, extension officers faced challenges when visiting farmers in this cocoa growing field as they are not mobile, they sometimes cannot reach them.

The extension officers themselves had problems. Some did not have motorbikes or fuel to travel. This means that farmers did not get regular advice or help with learning about irrigation. Lastly, farmers feedback on the lack of support from the government or other institutions. Some farmers did not know how to apply for help while others say that even when they tried, the process was considered too difficult and they ended up not getting any form of support. Others did not have training on new irrigation methods. This means they could not support farmers well. These findings align with SLF's recognition of constraints in financial and physical capital, and resonate with Totin et al. (2018) and Daum (2025), who argue that adoption depends on enabling institutional environments rather than technology alone.

Another critical part was the lack of information as a barrier. Some farmers knew about irrigation, others did not. This was worse in areas without mobile networks or community meetings. Sometimes, language problems also stopped clear

communication. Some farmers also fear risks, thinking if they invest in irrigation and the system breaks, they will be at loss and their money is gone. Others worried about using polluted water and hurting their plants ending up leaving the farm.

The findings clearly illustrate how the barriers to irrigation adoption are deeply rooted in the dynamics of the Sustainable Livelihoods Framework (SLF). The degradation of natural capital, particularly polluted streams from illegal mining, deforestation, and shrinking water bodies had severely undermined the availability of clean and reliable water sources essential for irrigation. The growing negative impact of environmental degradation was not just a side issue, it was a direct barrier to innovation. Irrigation may play a role in improving livelihood stability, but it exists within a broader set of factors including market conditions, health, and institutional support that also shape farmer experiences. Similarly, while some respondents touched on the notion of innovation, the theme requires careful interpretation to avoid overstating its presence or impact. Drip irrigation was mentioned as a smart way to save water. A few farmers used sprinkler irrigation for vegetables. These are signs that some farmers are open to trying new ideas, but they need training and support to use these innovations effectively.

6.3 Perceptions and Use of Irrigation Technologies

The farmers and extension officers in this study believed that irrigation can help improve cocoa farming. They have seen that relying only on rainfall was no longer promising and too risky. Some of them have seen how irrigation works well for other crops, like vegetables. This gave them hope that it can also work for cocoa. Most of the farmers believed irrigation can be useful, but they did not use it. This is not because they do not want to. It is because the systems are expensive or too technical which will require them to be trained. They lack the knowledge and skills. Advisory officers also agree that irrigation is good not because they are into it. They also pointed that the right kind of irrigation system for cocoa is drip irrigation, good but it costs a lot and farmers do not have the needed support to install it. This mirrors the SLF's emphasis on social and human capital, knowledge, education, and peer influence, AKIS's point that farmer engagement and relevance to local context are crucial in the uptake of innovations.

Some farmers mentioned they learned about irrigation from other farmers in cooperatives and farmer groups. This shows that they were open to new ideas. It also shows the power of peer learning. Although irrigation systems were seen as helpful, some of them such as sprinklers were not designed for cocoa. This is because cocoa is a tree crop. Cocoa trees need a different setup. So even if farmers want to use irrigation, they may not know how to make it work for cocoa.

On the otherhand, some service providers promoted modern systems like sprinklers and drip lines, farmers say these systems needed skills they did not have to maintain and manage it. This gap between advice and reality needs to be addressed. Irrigation system is not new to farmers, they know about it and they even want it. But they cannot always access it. Even when farmers are poor or isolated, many of them still try to adapt. They plant early, use shade, or learn from neighbours. Farmers find local ways to deal with drought, even when they did not have irrigation. Some farmers also mentioned learning from others in their communities. This is an example of community-based adaptation. When farmers teach each other, share tools, or join groups to learn, they are helping each other adapt together. These local efforts are very important and should be supported more by government and NGOs.

6.4 Access to Advisory Services

Advisory services can be very important in helping farmers learn about irrigation. But in many places, these services were not working well. Farmers said they did not get regular visits from extension officers. This was because there are too few officers for too many farmers. The challenge they faced on bad roads and lack of transport prevented extension officers from reaching cocoa farms. Without regular visits, farmers were left on their own. Many farmers still received advice face-to-face. But this method was not always possible, especially in remote areas. There is a need for other ways to share advice.

Another problem was that some advisory services were not centered on just cocoa alone, they also helped with vegetable farming. Some farmers mentioned while they have their own experience, extension officers needed more training. If officers did not understand irrigation, they could not teach it well. Advisory services played an important role that help farmers learn and apply new methods, and it fits with SLF's idea that support from institutions and policies is needed to improve farmers' lives.

Strength: A key strength of the study is its triangulation of perspectives, drawing on qualitative data from both farmers and service providers across public and private sectors. This multi-actor view provided a holistic picture of the constraints and opportunities in scaling irrigation. Moreover, the focus on cocoa, a crop traditionally seen as rainfed, adds novelty, particularly as climate variability increasingly challenges traditional production systems. The study also integrates environmental degradation (galamsey) as a factor in technology adoption, which has not been widely covered in cocoa irrigation literature. In the area of yield-water gaps and how perception aligns with observed productivity changes as observed contribution of this study. Advisory providers and COCOBOARD officials confirmed that irrigated cocoa fields show improved yields, especially during dry

spells. This shared observation supports the argument for scaling irrigation in cocoa production systems, especially under mixed-cropping models.

Weaknesses: However, the study is not without limitations. The sample size while diverse may not represent all cocoa-growing regions in Ghana. Secondly, irrigation use in cocoa remains in early stages, so findings were often based on pilot projects. While farmers expressed interest in irrigation, the study did not assess their actual financial capacity or willingness to pay, which would be critical for designing viable interventions. These were discussed mainly in response to field limitations rather than proactively explored gender, age, land size during interviews.

While my findings reveal a mix of environmental, institutional and technical challenges that threatens both the perception of the issue and the recommendations. One strength from this study includes voices from multiple actors, advisory providers, extension officers, institutional actors like Cocoboard and farmers. This helped to capture a more complete picture of the challenge. Another area that cocoa farming which is usually considered a rainfed crop but with climate change, an exploration on how irrigation can be well integrated as a response to climate challenges can not be overemphasized. The data showed that while irrigation is widely seen as a necessity for climate adaptation and productivity in cocoa farming, the issue of infrastructure, finance, water quality and informational barriers need to be tackled. While advisory services are also critical in their role, they still need some sort of support to be more effective and efficient in their service delivery. Therefore, it is pertinent to improve on partnerships between private providers, farmers groups and government for scaling irrigation adoption in cocoa production.

Although the Sustainable Livelihoods Framework (SLF) was mentioned, the analysis did not go deep into how different types of capital (like financial, natural, or social capital) affect irrigation use. For instance, I did not look closely at farmers' land sizes, incomes, or ownership of equipment. This could be improved by showing how these factors influence who adopts irrigation and why. There exist deep-rooted barriers that prevent widespread adoption such as poor infrastructure, weak extension support, illegal mining. The SLF and AKIS are both frameworks that highlight the importance of integrating different forms of capital and knowledge systems to improve agricultural practices, and more detailed analysis of these could strengthen the study's findings. While advisory services are important, this study shows that they are not the biggest barrier to adopting irrigation. The most serious problems are environmental, such as polluted water from illegal mining, and financial, such as the high cost of irrigation systems. This is different from the idea in the introduction that better advisory alone can solve the problem. In reality, even well-informed farmers are unable to adopt irrigation if water is

unsafe or the costs are too high. Therefore, solutions must go beyond training and focus on improving water quality and reducing financial risks for farmers..

6.5 Vulnerability and Uneven Adaptation

This study found that vulnerability to climate stress in cocoa farming is shaped not just by biophysical exposure alone like, drought, but also by a range of social, economic, and institutional conditions that limit farmers' options for adaptation.. This is because farmers often times are at risk especially farmers that lack access to extension services, clean water, financial support and irrigation systems are the least equipped to adapt. For example, aged farmers above 50 years who don't have labour support, and those in the areas affected by illegal mining, are disproportionately exposed to environmental and economic shocks. Regardless of how informed they are about changing weather patterns and all the potential importance of irrigation technology, their ability to respond is constrained by institutional neglect, economic precarity, and degraded ecosystems.

Vulnerability is socially produced: adaptation is not only about capacity, but also about access to resources, justice and governance. Even well-intentioned advisory systems may unintentionally introduce inequality in a situation when outreach is limited or biased toward better-connected farmers leaving out other farmers not well connected. At the same time, the data revealed important instances of innovation. Some farmers experimented with manual irrigation or water harvesting for vegetables, while others engaged in informal knowledge sharing. These act reflect their adaptive capacity even with the systemic issues and demonstrate that farmers are not passive recipients of advice, but active agents navigating uncertainty. Wellbeing emerged as a central concern in farmer narratives. Low yields for cocoa, increasing costs of input, and unreliable rainfall were described not only in technical terms but as personal stress, threats and hardship to long-term livelihood security. This reinforces that adaptation must be evaluated not just in terms of productivity, but in how it affects people's quality of life.

Similarly, farmers described learning from one another and working together to address shared challenges, such as experimenting with irrigation or managing water access collectively. Using the example of some farmers that relied on their neighbours advice. These efforts reflect potential of locally driven solutions, especially when formal advisory systems are weak. However, such community strategies cannot fully resolve systemic failures. Suggesting that to make irrigation a viable and equitable adaptation strategy, the use of policies should target the structural drivers of vulnerability that includes weak extension networks, poor infrastructure and degraded water sources while supporting farmer-led innovation and social resilience. The fact that all farmer respondents were over 50 years old

highlights an important dimension of vulnerability, demographic ageing in smallholder cocoa farming. Older farmers may have valuable experience and local knowledge, but they may also face challenges in adopting new technologies due to physical limitations, risk aversion, or lack of long-term investment incentives. This can affect their ability to engage with innovations such as irrigation, and underscores the need for targeted support that considers generational dynamics in adaptation planning.

7. Conclusion and recommendations

This concluding section summarises the key findings of this study. It includes the contributions to the body of knowledge while the study used the Sustainable Livelihoods Framework (SLF) to explore cocoa farmers' access to irrigation technology as a strategy for climate change adaptation in Ghana. Drawing on insights from qualitative interviews, this section also provides recommendations at the institutional, and farmer support levels. It also reflects on study limitations and suggests avenues for further research. The Sustainable Livelihoods Framework (SLF) and Agricultural Knowledge and Innovation Systems (AKIS) are critical to understanding the issues and potential solutions for improving the resilience of farmers who farm cocoa in Ghana, as it relates to irrigation technology adoption and adapting to climate change.

In order to bridge the irrigation yield water gap, SLF and AKIS emphasis on institutional support can improve extension services, strengthening community-based organizations and enhance financial access that can support the adoption of irrigation technologies. Based on the SLF, human capital is an important asset for farmers. So, investing in training programs for farmers' improvement on their technical skills using irrigation systems is needed. AKIS focus on ensuring knowledge exchange not only between institutions but also between farmers, researchers, technology providers, institutions and NGOs to ensure that farmers have the necessary support and knowledge to implement climate-smart practices. Therefore, solving these barriers needs more than just tools or advice. It needs action on clean water, better roads, more support staff, and easier ways to get access to resources. This research can provide valuable insights into the specific needs of cocoa farmers and the institutional reforms necessary to enhance irrigation adoption. Therefore, both public private and peer advisory can be used in the area if trained and enabled. They are all trusted and have a common view on the issue and the opportunity with the right support, both types of advisory services can work in tandem to build trust, increase knowledge, and ultimately facilitate broader adoption of practices that can improve resilience and productivity.

This study focus was not directly on policy or enforcement mechanisms, farmers and other irrigation expert pointed out impact of illegal mining especially on water sources and its negative effect it has on sustainable cocoa farming. Moreover, the interviews suggest a strong informal knowledge-sharing culture among farmers.

These insights contribute to the literature by emphasizing the role of social capital and local innovation networks in shaping technology uptake in climate-vulnerable regions. These observations suggest the need for broader institutional attention to

safeguard water resources and soil, which are relevant for long-term agricultural productivity and farmer, which is not sufficiently acknowledged in current AKIS models. These efforts align with broader environmental conservation goals and contribute to achieving the United Nations Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation) and SDG 15 (Life on Land).

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Appendix 1

Annex 1:

Protocol Interview questions:

Survey for Farmer Advisory Service Providers on Irrigation Technology with Informed consent for all Interviewees.

Greetings: Good morning/afternoon. Thank you for taking the time to participate in this interview.

Purpose: We are conducting a study to assess farmer advisory services and the adoption of irrigation technology for climate adaptation and productivity in cocoa farming in the Ashanti Region.

Section A: Demographic Information

1. Name:

Gender:

- Male
- Female
- Other
- prefer not to say

2. Position/Role:

- Extension Officer
- Private Consultant
- NGO Worker
- Irrigation Equipment Company Representative
- Other (Specify)

3. Years of Experience in Advisory Services:

- Less than 5 years
- 5-15 years
- Over 15 years

4. Region of Operation:

- Ashanti
- Ahafo Ano Southwest District

Section B: Interview Questions

Sections	Areas	Question1	Question 2	Question 3
C	Current challenges and Future challenges in cocoa system	is irrigation a solution to adapt in cocoa system? Are there infrastructure challenges that affect irrigation uptake? (YES/NO)	what are the opportunities for farmers or constraints	How are financial constraints resolved to enable uptake and what else is needed

D	Promotion of irrigation technologies and farmer demand for cocoa versus conventional rainfed crops.	What irrigation technologies are currently promoted to cocoa farmers, and which are being accepted or rejected? How do you assess water availability and quality in the region when setting up irrigation systems for cocoa farming?	What policies or frameworks has your institution developed to support advisory services that help cocoa farmers adapt to climate-related challenges?	Is there improvement on irrigated cocoa farm compared to rainfed cocoa? (YES/NO) Do you collaborate with irrigation service providers for irrigation adoption among cocoa farmers? (YES/NO)
E	Irrigation's role in enhancing drought resilience and managing excess water (flood) risks.	When do FASP think irrigation is needed? Why do they think irrigation is needed, how much irrigation? How do they quantify that irrigation?	How do farmers prioritise between cocoa and maize? Do they prioritise irrigation over rainfed systems for crops or livestock?	What roles do advisory, and extension services play in helping farmers manage irrigation for both droughts and floods?
F	Provision of climate adaptation solutions for water scarcity to farmers.	How do you help farmers prepare for droughts or dry seasons? Do farmers rely more on their own experience and innovation? Yes/No	How do you educate cocoa farmers on the importance of irrigation in mitigating climate variability and its impacts?	How can irrigation help cocoa farmers deal with unpredictable weather? what types have been experienced, what is the impact?
G	Perceptions of extension and advisory institutions on the yield water gap in cocoa.	How do you assess the impact of the current rainfed system on crop productivity in your region?	Do you think farmers are experiencing drought? YES/NO	In your opinion, how serious is the yield water gap issue in rainfed farming?

H	Future consideration	Do you believe that irrigation will become more important in cocoa farming in the future? Why or why not?	What role do you see your organization playing in the future expansion of irrigation technology in cocoa farming?	Can you share any success stories where irrigation technology significantly improved farm productivity? And unsuccessful stories?
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Farmer Interview Questions:

How do you get advice?
How do you water your cocoa farms during dry season
Have you noticed any changes in the weather
Do you use irrigation on your farm?
Have you faced problems with water like not having water for your crops
Which water sources do you use for irrigation
Do you think irrigation would help improve your cocoa farms
Are there other farmers you know that use irrigation

Table 3. Profile of all the respondents including their years of experience

Interview number	1	2	3	4	5	6	7
Gender	M	M	M	M	M	M	M
Position/ Role:	Extension officer	Extension Service Provider	Advisory service provider	Ministry Of Food and Agricultural (MOFA)	Irrigation Provider	Irrigation provider	Irrigation provider
Years of Experience:	5-15	5-15	5-15	Over 15 years	Over 15 years	5-15	5-15
Region of Operation	Ashanti Ahafo Ano	Ashanti Ahafo Ano	Accra, Ghana	Ashanti Ahafo Ano	Ashanti Ahafo Ano	Ashanti Ahafo Ano	Ashanti Ahafo Ano

	Southwest District	Southwest District		Southwest District	Southwest District	Southwest District	Southwest District
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Interview number	8	9	10	11	12	13	14
Gender	M	M	M	M	M	M	M
Position/ Role:	Irrigation Provider	Irrigation Provider	Extension officer	Cocoboard	Extension Officer	Advisory service provider	Irrigation Service provider
Years of Experience in Advisory Services :	5-15	5-15	5-15	5-15	Over 15 years	5-15	5-15
Region of Operation	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Kumasi Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District

Interviewee number	15	16
Gender	M	M
Position/Role:	Irrigation Provider	Irrigation Service Provider
Years of Experience:	5-15	Over 15 years
Region of Operation	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District

Interviewee number	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Gender	M	M	M	M	M
Position/Role:	Farmer	Farmer	Farmer	Farmer	Farmer
Years of Experience in Advisory Services:	5-15	5-15	5-15	5-15	Over 15 years
Region of Operation	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District	Ashanti Ahafo Ano Southwest District

Details of the study participants with reference to their expertise, roles, and perspectives that contribute to understanding irrigation adoption in cocoa farming. Annex 3 description of respondents that participated in the interview during the period of data collection (Author 2024)

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